PEER REVIEW OF EPA'S
INDUSTRIAL WASTE AIR MODEL

SUMMARY DOCUMENT

September 23, 1999

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INTRODUCTION CHAPTER 1

The U.S. Environmental Protection Agency (EPA) and representatives from 12 state environmental agencies have developed a voluntary *Guide for Industrial Waste Management* to recommend a baseline of protective design and operating practices to manage industrial non-hazardous waste throughout the country. Since the Guide recommends risk-based approaches for choosing emission controls for Waste Management Units (WMUs), a user friendly air model for conducting a risk assessment was included. The Industrial Waste Air Model (IWAIR) is an interactive computer model aimed at estimating human health risk from volatile compounds originating from industrial WMUs . Intended for the use by the public, facility managers, and state, tribal and local agencies, one of the major applications of IWAIR will be to determine if emissions from WMUs pose a risk that warrant additional emission controls. In addition, IWAIR can be used to calculate waste constituent concentrations that can be protectively managed in a WMU

IWAIR is composed of three major components: an emission model, a dispersion model, and a human health risk model. The emission model component estimates volatile emissions from various waste constituents placed in WMUs; the dispersion model calculates fate and transport of constituents through the atmosphere and their ambient concentrations at specified receptor locations; and the human health risk model calculates resulting cancer and non-cancer risk to nearby workers and residents. In estimating whether specific waste management practices pose an unacceptable risk to human health, IWAIR requires only a minimum amount of data such as ZIP code of facility location, major WMU characteristics, waste characteristics, and information on the receptor.

The purpose of this report is to present results of an external peer review organized by the Office of Solid Waste (OSW) to evaluate IWAIR model performance and applicability for its intended use. OSW contracted Industrial Economics, Incorporated (IEc) to conduct the peer review. IEc assembled a team of four experts, including one in air emission modeling, two in air dispersion modeling, and one in human health risk assessment. In selecting the peer reviewers, IEc sought out experts who were highly qualified to evaluate model performance, data sources and assumptions used in the model, and quality of the software and documentation. IEc also sought to identify experts who had sufficient experience with similar models be able to make specific recommendations for improvement in areas of potential model weaknesses.

Considering the model's intended applications, the four experts found the IWAIR model to be an appropriate tool for preliminary screening purposes. However, peer reviewers identified several potential areas for model improvement, including the model's representation of meteorological variations throughout the United States, its focus on the inhalation of vapor emissions from WMUs, its treatment of semi-volatile compounds given this focus, potential instability of its cancer risk calculation code, and clarity of the model's Technical Background Document.

This report presents the results of this peer review effort. Chapter 2 provides a brief description of the model background, including the regulatory framework, purpose of the model, and expected users. Chapter 3 outlines the process followed in conducting this peer review. Finally, key issues raised by the peer reviewers are summarized in Chapter 4. This chapter also includes a complete list of the four peer reviewers' responses to specific questions raised in the charge to the peer reviewers. In addition, resumes of the peer reviewers, the charge to the peer reviewers, and a full copy of each peer reviewer's comments are included as Appendices to the report.

Industrial waste typically consists of process waste associated with numerous types of manufacturing facilities. Consequently, a variety of non-hazardous industrial wastes are placed in WMUs such as surface impoundments, landfills, waste piles, or land application units. The IWAIR model estimates risks to human health posed by volatile emissions of 95 different constituents from these four types of WMUs.

IWAIR is composed of three major components, incorporating expertise from the scientific fields of emission modeling, dispersion modeling, and human health risk assessment. IWAIR's emissions model component estimates volatile emissions originating from waste placed in WMUs. The dispersion model component estimates fate and transport of constituents through the atmosphere and determines ambient air concentrations at specific receptor locations. The risk assessment model component calculates the risk to exposed individuals or, alternatively, backward calculates waste constituent concentrations that can be protectively managed in the unit given a specified target risk level. The following briefly describes major components of the IWAIR model. Detailed descriptions can be found in Industrial Waste Air Model Technical Background Document (EPA 530-R-99-004, December 1998).

The emissions model selected for incorporation into IWAIR is EPA's CHEMDAT8. Within IWAIR, the emission module estimates emissions of waste constituents based on input data describing the nature of the wastes and constituent concentrations, type of WMU, and other facility-specific information. To ensure IWAIR's applicability for a wide variety of sites, user-specified site-specific emissions rates can be used to override those factors calculated.

IWAIR's dispersion modeling component estimates dispersion of volatized contaminants and determines ambient air concentrations at specified receptor locations. The dispersion module uses default dispersion factors developed with EPA's Industrial Source Complex, Short-Term Model, version 3 (ISCST3). IWAIR incorporates default dispersion factors for a variety of scenarios, including 29 meteorological stations representing nine climate regions of the continental US, four WMU types, various surface area sizes, six receptor distances, and 16 directions in relation to the edge of the unit. Similar to emissions factors, the user may choose to enter user-specified dispersion factors to override values calculated by the model.

IWAIR's risk module, combines the constituent's modeled air concentration (derived from the emissions and dispersion components of the model) with receptor exposure factors and toxicity benchmarks to calculate cancer and non-cancer risks associated with waste managed in WMUs. In calculating human health risk, the model employs default values for exposure factors, including body weight, inhalation rate, exposure duration, and exposure frequency.[1]

[1] Default values are based on EPA's Exposure Factors Handbook, EPA, 1997.

IWAIR is an environmental computer model intended to form part of the scientific basis for decision making; thus, in keeping with EPA's peer review policy, OSW chose to submit it for external peer review involving independent experts from relevant disciplines. The primary purpose of this peer review is to assist OSW in the following tasks:

- Documenting the quality and credibility of the model;
- Evaluating its scientific and technical model performance, describing factors of uncertainty and weaknesses associated with the model;
- Suggesting appropriate amendments to the model; and
- Improving the understanding of technical and scientific limitations of the model and its appropriate application.

In order to identify qualified peer reviewers, Industrial Economics, Inc., (IEc) contacted 17 experts with expertise in emission modeling, air dispersion modeling, and/or human health risk assessment. These included a number of experts that IEc identified from its knowledge of these fields of study, as well as several identified by OSW as candidate reviewers. Among these candidates, four experts were found to be most qualified to conduct the peer review (see Exhibit 1).

Criteria for selecting most qualified peer reviewers included their qualifications to consider the overall model structure, methodology, data sources, assumptions, input parameters, and the quality of IWAIR's user interface. The specific criteria considered in selecting the peer reviewers were:

- The reviewers must have multiple years of experience in at least one of the following relevant disciplines -- air dispersion modeling, emissions modeling, or risk assessment;

- The reviewers must be from different institutions of employment;

- The reviewer(s) selected as expert(s) in air modeling must have experience in national scale and site-specific air modeling, and preferably have had experience in working with ISCST3 and CHEMDAT8;

- It is preferable that reviewers selected for their expertise in using air models also have experience in model development;

- The reviewers must have at least a Master's level of education, or have had enough experience in air modeling or risk assessment to substitute for this level of education.

The qualifications of the four peer reviewers selected, including their scientific expertise and relevant project experience, are summarized in Exhibit 1. Craig Mann was chosen as reviewer for IWAIR's emission modeling component. As evidenced through his previous work for EPA, he has extensive expertise in emission modeling, review of emissions models, as well as additional expertise in dispersion modeling. Douglas Fox and Arthur Schatz were selected for the review of IWAIR's dispersion modeling function. Both reviewers have extensive expertise in fate and transport modeling for a variety of clients, including EPA. Arthur Schatz also has supplementary expertise in emission modeling and human health risk assessment. Finally, Alan Eschenroeder was selected as the primary reviewer for the model's human health risk component. His work on human health risk assessment includes previous work on municipal waste issues and VOC emissions. In addition, he has supplementary expertise in air dispersion modeling. Resumes of the peer reviewers are provided in Appendix A.

In order to conduct the peer review, IEc sent the four experts copies of the IWAIR model, the User's Guide, and the Technical Background Document (TBD). IEc also sent a detailed "charge", developed by the EPA, which contained information on the background of the project and the regulatory framework within which the model will be applied, as well as a list of 31 questions on specific aspects of the model. A copy of the charge is included as Appendix B to this report.

IEc convened a conference call with the peer reviewers (the EPA was not included) one week after these materials were sent out to ensure that each of the reviewers received all of the materials, and that they understood the background for model development, its intended use, and the questions posed in the charge. Furthermore, IEc clarified which questions should be addressed by the reviewers according to their areas of expertise. This ensured comprehensive coverage of the questions posed in the charge and avoided extensive overlap of areas reviewed.

Each of the peer reviewers had 40 hours to conduct their review of the model. Upon receiving the drafts from the reviewers, IEc reviewed the drafts for their clarity and comprehensiveness. Subsequently, IEc contacted each peer reviewer to discuss details of the draft, such as potential for improvements in clarity and for additional comments based on the reviewer's analyses and expertise. The peer reviewers then made revisions and submitted their final reviews.

Exhibit 1

SUMMARY OF PEER REVIEWERS' QUALIFICATIONS

Name/Affiliation	Expertise: Air Emission	Expertise: Air Dispersion	Expertise: Risk Assessment	Relevant Experience: Years	Relevant Experience: Description of Experience in Model Development, Review, and Research
Eschenroeder, Alan, Ph.D. Principal, Alanova, Inc.		✓	★	30	• Managed comparative assessment of human health and ecological risk associated with alternative municipal waste management approaches in Puerto Rico. Alternatives include landfilling and waste-to-energy facilities in each of four prototype environments. • Currently reviewing existing dispersion modeling of emission changes due to a VOC emission trading program in California.
Fox, Douglas, Ph.D. Principal Fox and Associates, Inc.		★		>30	• Served as one of the four founding members of the initial peer review activity for regulatory models initiated by EPA. This activity led to the development of the EPA *Air Quality Dispersion Modeling Guidelines.* • As a member of the *American Meteorological Society/EPA Dispersion Modeling Review Committee*, led efforts for developing statistical methods for model evaluation and validation. • Currently engaged in the development of regulatory models in support of EPA's developing policies on fine particulate and regional haze.
Mann, Craig Director of Training and Program Development, Environmental Quality Management, Inc.	★	✓		16	• Reviewed and validated emission models for EPA to assess air impacts during the remediation of superfund sites. • Developed two simulation models for vapor emissions from soils that presently reside on the EPA NCEA and OSWER websites. • Developed the air pathway exposure assessment for calculating EPA's *Soil Screening Levels* (SSLs) for the *Superfund* program. This work included theoretical modeling of vapor-phase and particulate matter emissions and dispersion from contaminated surface and subsurface soils.
Schatz, Arthur Senior Risk Assessor, Parsons Engineering Science	✓	★	✓	18	• Directed development of the *Exposure Model for the Soil-Organic Fate and Transport* (EMSOFT) model for EPA. • Reviewed various risk assessments and models including EPA's organic air emission risk assessment for hazardous waste TSDF for an industry trade association. • Completed health risk assessments for numerous CERCLA and RCRA sites as well as many toxic air pollutant sources, involving a wide variety of emissions and exposure modeling techniques.

★ Extensive Experience
✓ Supplementary Expertise

PEER REVIEWERS' COMMENTS CHAPTER 4

Each of the reviewers was asked to answer general questions about model performance, ease of use and the quality of documentation. In addition, the reviewers were asked to focus on specific questions addressing one or more of three model components. The reviewers' "assignments" are summarized below.

- **Alan Eschenroeder** -- focus primarily on the human health risk assessment component of IWAIR and provide additional comments on the dispersion component.

- **Douglas Fox** -- focus on the air dispersion component of the model.

- **Craig Mann** -- focus on the emissions component of the model and provide additional comments on the dispersion component.

- **Arthur Schatz** -- focus primarily on the air dispersion component of the model and provide additional comments on the human health risk assessment and emissions components.

In this chapter, we present the peer reviewers' comments on the IWAIR model. First, we summarize major issues raised by the peer reviewers. This is followed by a complete list of the peer reviewers' responses to specific questions raised in the charge. All of the comments are attributed to individual reviewers using their initials: AE -- Alan Eschenroeder, DF -- Douglas Fox, CM -- Craig Mann, and AS -- Arthur Schatz.

<u>Overview of Key Issues Raised By Peer Reviewers</u>[2]

1. **The primary application of the IWAIR model should be for preliminary screening purposes.**

   The User's Guide, and perhaps an initial model screen, should caution the user about the large uncertainty inherent in this model, its conservatism, and the limits of simulations run with very little data. **(AS, AE)**

2. **Using dispersion factors based on 29 meteorological stations, may offer a false sense of precision, given the potential for variations in meteorological conditions.**

   Twenty-nine meteorological stations may not be sufficient to represent meteorological variations throughout the U.S. Meteorological data are not usually regionally defined and may exhibit greater variations within regions than among regions. Peer reviewers suggested the following alternatives:

   - Add a subroutine that allows the user to input windrose data and select among the 200 locations for best match. This subroutine would include an algorithm to search a meteorological data set and to identify the meteorological station that best represents local conditions. **(DF)**

   - Consider omitting geographically defined dispersion factors. The difference between the highest and lowest unit air concentrations (UACs) among stations seems small compared to the uncertainties inherent in the model, such as emission estimates generated by CHEMDAT8 and the toxicity benchmarks used in risk analysis.[3] It may be more appropriate for EPA to use a single, conservative dispersion factor based on a statistical analysis of the highest UACs from a number of meteorological stations (e.g., the upper 90% confidence limit about the mean of these values). **(AS)**

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[2] The order in which key issues raised by peer reviewers are presented is not intended reflect potential importance or to suggest priorities for OSW in responding to peer review comments.

[3] The difference between the highest and lowest UACs among stations is only a factor of two (see Tables 3-4 and 3-5 of the Technical Background Document).

3. Given that IWAIR does not account for risks associated with particulate emissions, the model should not include compounds with very low vapor pressure.

The list of chemicals considered by IWAIR includes some semi-volatile compounds that are more likely to be associated with particulate emissions than vapor emissions (e.g., benzo(a)pyrene, 7,12-dimethylbenz(a)anthracene, phthalic anhydride, and benzidine). In addition, important semi-volatile contaminants such as members of the PCB family are missing from the list. Peer reviewers suggested the following alternatives **(AS, AE)**:

- Include all of the semi-volatile compounds along with additional significant pathways.
- Consider eliminating semi-volatile compounds from the list. In this case, it should be stated clearly in the TBD and User's Guide that the model is intended for use with volatile compounds only.

4. IWAIR's calculation of cancer risk seems to be unstable.

While it is possible to duplicate IWAIR's results for non-cancer risk, the manual calculation of cancer risk can yield results different from those produced by IWAIR (see Art Schatz's calculation examples for cancer risk associated with vinyl chloride in landfills and for cancer risk associated with benzene in surface impoundments). This may be due to a bug in IWAIR's cancer risk calculation code. In seemingly duplicate model runs, IWAIR sometimes produces different results for cancer risk. The model calculation code for cancer risk should be reviewed for bugs. **(AS)**

5. IWAIR's default chemical - specific biorate constants may result in artificially high removal rates.

Biodegradation algorithms employed in IWAIR are tied to the assumption that all wastes for land application are similar to benzene in biodegradation potential. Some wastes, however, may not fit this assumption due to high initial contaminant concentrations or the presence of contaminants that are toxic to naturally occurring microorganisms (e.g., halogenated wastes). In these cases, the default chemical-specific biorate constants as well as the default biomass concentrations may result in artificially high rates of removal. Peer reviewers suggested the following alternative:

- Add a feature to the model that allows users to specify user defined decay constants, including an option to set it to zero. **(CM,AS)**

6. IWAIR does not list ambient air concentrations at the receptor.

When forward calculating risk, the IWAIR model calculates the emission rate, the dispersion factor, and the resulting incremental risk and/or hazard quotient. While these values are sufficient for determining the need for emission controls, it would also be advantageous if the model provided the estimated ambient air concentration at the receptor. The model output could then be used to compare the estimated exposure point concentration to regulatory acceptable air concentrations (e.g., State air toxics criteria), which may be helpful to some users of the model. **(CM)**

7. IWAIR exhibits a counterintuitive sensitivity to the number of cells within a landfill.

For a given mass of waste disposal, the IWAIR model estimates higher emissions for a greater number of cells. However, one might expect a landfill with more cells to have lower emissions due to the smaller area of cells and their shorter durations of operation. IWAIR's sensitivity to the number of cells is based on the assumption built in the model that the entire mass of waste in each open cell is placed at the beginning of the interval. Because the emission rate decreases with time as the chemical evaporates, the emission rate is higher during the first month than the second month. If all of the waste is assumed to be placed in the cell at the beginning of the interval, the average emission rate for a cell open for one month will be higher than the average emission rate for a cell open for two months. The following alternative was suggested:

- EPA may consider using a uniform disposal rate over the interval in which the cell remains open. A landfill model with a uniform disposal rate may exhibit less sensitivity to the number of cells in the landfill. **(AS)**

8. While extensive sensitivity studies of ISC3 are presented in the TBD, no comparable data are presented for CHEMDAT8.

EPA may consider augmenting information presented about CHEMDAT8 (e.g., adding CHEMDAT8 sensitivity studies) to match the level of information provided for ISC3. **(AE, AS)**

9. The Technical Background Document does not provide sufficient information and should be reorganized.

The TBD does not always provide sufficient information on algorithms and/or logical steps employed in the IWAIR model. (e.g., treatment of addition of waste to WMU, calculation of emission rates performed by IWAIR). To improve the TBD, appropriate information on CHEMDAT8 from *Air Emissions Models for Waste and Wastewater*, U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-453/R-94-080A, (November 1994) should be included in the IWAIR TBD. This information should be rewritten in a sequential order with a minimum of theory. The IWAIR TBD could refer the user to EPA's 1994 document for a more thorough explanation of the theoretical considerations. **(AE, CM)**

10. For screening purposes, it is useful to display the sum of health hazard quotients.

While non-cancer risk should not be additive if they represent different endpoints, it is useful to provide information on health hazard quotients associated with each constituent as well as the sum of health hazard quotients, known as the hazard index, associated with all constituents present. This overall hazard index is useful for screening purposes. In addition, the model should provide subtotals of the hazard quotients for constituents having the same end points. **(AE)**

11. The linear interpolation between two areas with known dispersion factors can be augmented.

IWAIR relies on linear interpolation between two areas with known dispersion factors to estimate dispersion factors for various surface areas. Based on a visual analysis of a plot of UACs versus Surface Areas for 2-meter high waste piles, it appears that the linear interpolation may underestimate the UAC by up to 20% in some regions of the graph (see Figure 3-6, page 3-16 in the Technical Background Document). Following alternatives have been suggested **(AS)**:

- EPA may decide to run ISC3ST for more areas to require less linear interpolation between adjacent size areas.

- The linear interpolation routine may be applied to the logarithms of the adjacent areas. This approach tends to equalize the distance between adjacent known points on the curve.

12. The emissions model for surface impoundments does not include algorithms for estimating emissions from oil film layers.

Unlike emission models for Land Application Units, active landfills, and waste piles, the emission model for surface impoundments does not include algorithms for estimating emissions from oil film layers at the surface of the impoundment. **(CM), (AS)**

13. UACs listed in the Technical Background Document may be higher than values used in the model.

Table 3-4 of the TBD (page 3-11) shows the UAC for Chicago as 10.505 mg/m3/ mg/s-m2, which is four times the dispersion factor actually used by IWAIR. There appears to be a systematic error in Table 3-4. **(AS)**

14. **All assumptions and limitations of each model input should be included in the IWAIR TBD.**

In addition, consideration should be given to inclusion of simple tables for specifying the relative sensitivity and relative uncertainty of each model input parameter value. This would help the user to determine how the use of parameter values other than the default values would effect model outcomes. **(CM)**

<u>Peer Reviewers' Responses to Specific Questions in the Charge</u>

This section of the report presents the peer reviewers' responses to specific questions in the charge. The questions are presented in bold, followed by the full text of responses provided by the reviewers. The questions and responses are listed in five major categories, as they were defined in the charge: (I) overall model performance; (II) specific model features; (III) parameters used for WMUs; (IV) risk assessment; and (V) quality of software and documentation. In addition to responding to the 31 specific questions posed in the charge, the reviewers offered supplemental comments in their reports to IEc. These comments are presented at the end of this section.

I. Overall Model Performance

1. **Given the goals of the model, is IWAIR an appropriate tool to use? Does the model provide a reasonably accurate representation of the risk from a unit? Does the model perform well over a range of input values and scenarios? How can the model be improved?**

- **AE:** a) Yes. b) Yes, if its application is restricted to the volatile compounds on the list. c) The model does not always perform well over a range of input parameters. Some of the limit values are lower than soil saturation values, thereby failing to address cases within the realm of possibility. The model can be improved by informing the user how default values are used. This is never mentioned. Also, it would be helpful to provide help screens for entry level users that explain how equations listed in the TBD produce numbers on the various model screens.

- **DF:** a) Yes, it is appropriate. b) In my opinion, it does provide a risk estimate that is of sufficient accuracy to provide a reasonable estimate based on the direct inhalation pathway associated with a specific site. c) I ran the model over a wide range of input values and scenarios, and found it to perform well, dispersion values were appropriate based on my experiences and screens and results were without any noticeable flaws. The only error I encountered was a “Runtime Error ‘13’ Type Mismatch” a few times when I had added and removed chemicals on Screen 2. This happened about three or four times, but it was not a regular or consistent bug, I found no particular pattern to it. d) One area of improvement would be in the treatment of meteorological data.

While the selection of 29 meteorological stations as being representative appears to have statistical validity based on earlier work, it nevertheless represents a weakness in the approach. Meteorological data are not regionally defined and use of regional representations invariably introduces error into a calculation. In my opinion, for the purposes of this modeling and based on the nature of the calculation, looking over a long time period at accumulated risk, it is acceptable to use the 29 representations. However, I think accuracy would improve if local meteorological data could be used (as allowed in the model) where ever possible. In answer to Question 8b, I suggest how I think the use of on-site meteorology might be better accommodated.

- **CM:** The IWAIR model seems to offer a reasonable mathematical approach for estimating volatile emissions from the four types of waste management units (WMUs) included in the model. As to the accuracy of the emission models, no empirical data are offered in the Industrial Waste Air Model Technical Background Document (TBD) for comparison. Brief discussions of empirical studies are offered in the *Air Emissions Models for Waste and Wastewater*, U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-453/R-94-080A, November 1994, hereafter known as EPA (1994). This document is considered to be the background information document for the EPA CHEMDAT8 emission model; all of the emission equations used in the IWAIR model are taken from this document. A cursory summary of the results of these empirical studies can be found in Appendix A of EPA (1994). The author is correct in his assertion of a paucity in empirical studies with which model estimates can be compared. Therefore, this reviewer cannot make any judgements about the accuracy of the IWAIR emission models.

- **AS:** Model Goals:

  - Reasonable estimates of risk from a specific unit for direct inhalation
  - Simple, so can be run by users with different levels of knowledge and experience, including the public
  - Capable of running with very little data (enables public to use)
  - Flexible; user can enter alternative emissions data, dispersion data, and/or toxicity benchmarks

  a) IWAIR clearly meets the final three stated goals, as summarized above. It is simple enough for the user to navigate and enter inputs in the appropriate form. It can be run with very little real data. And, IWAIR has the ability to accept emission rates, dispersion factors and toxicity benchmarks provided by the user in lieu of the embedded estimation approaches (i.e., CHEMDAT8, ISC3ST-derived dispersion factors, and built-in RfCs, URFs and CSFs). The most important question here is whether or not IWAIR provides reasonable estimates of risk via inhalation for a given waste management unit. This is a difficult question to answer with much certainty. The ease of use of this model and the ability of users with little or no experience with emissions estimation, dispersion modeling or risk assessment to enter numbers makes this model extremely susceptible to "Garbage In – Garbage Out." While this model may be useful for preliminary screening of facilities for risk, the Users Guide, and perhaps an initial model screen, should caution the user about the large uncertainty inherent in this model and the limits of simulations run with very little data. c) I conducted only a limited sensitivity analysis of the model to ranges of input values and general performance evaluation. In many cases, IWAIR's results varied with individual parameter value changes as expected. As discussed below, there appear to be calculation problems that need to be corrected. d) This model needs continued review and work to correct calculation errors, output presentation errors and other bugs.

2. **A user of IWAIR is given one of two results, the risk from the unit or the concentration of a chemical that can be present in the unit to remain under a certain risk threshold. The intention of IWAIR is to provide information to the user on whether or not emission controls should be placed on a waste management unit. Are the types of results that IWAIR provides appropriate for this analysis? If not, what results would be more appropriate for determining whether or not a waste management unit should have emission controls?**

- **AE:** The results given are appropriate. Going any farther with interpretation would push the user into forced choices in risk management. Some cautionary labeling might be added to the results screen to remind the user of the model's limitations.

- **DF:** Yes, they are very appropriate. I can not think of a better way to think about emission controls.

- **CM:** When forward calculating risk, the IWAIR model calculates the emission rate, the dispersion factor, and the resulting incremental risk and/or hazard quotient. These values would be sufficient for determining the need for emission controls if the need is based solely on risk. It would also be advantageous if the model listed the ambient air concentration at the receptor. These data could then be used to compare the estimated exposure point concentration to regulatory acceptable air concentrations (e.g., State air toxics criteria). It must be remembered, however, that the present dispersion factors calculated by IWAIR represent annual average values only and cannot be compared with regulatory acceptable ambient concentrations based on less than an annual average (e.g., 1-h ave., 24-h ave., etc.). If dispersion factors could be produced for less than annual average exposure periods, the model would be much more useful as a screening tool for directly comparing predicted air concentrations to regulatory acceptable air concentrations. One option for calculating less than annual average dispersion factors would be to use the EPA SCREEN3 dispersion model to estimate worst-case 1-h average air concentrations at the appropriate receptor distance. From these data, the 1-h average concentrations may be converted to 3-h, 8-h, or 24-h averages using the EPA dispersion correction factors found in the Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants (Revised), U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-454/R-92-024.

- **AS:** IWAIR may be useful as an initial step toward assessing the need for controls on a specific WMU. IWAIR provides the chemical concentrations in waste and the emission rate for each chemical associated with a risk level for a WMU. However, IWAIR cannot perform this calculation for total cancer risk from a group of chemicals (there would be many solutions to this problem). To the extent that IWAIR shows how one might reduce concentrations in waste, or emission rates, IWAIR provides useful results.

  However, there is so much uncertainty and conservatism built into this model, that it is unlikely that IWAIR would be used directly to evaluate controls. IWAIR may serve as a simple Tier 1 screening tool. But if IWAIR suggests unacceptable risks, the next appropriate step is more site-specific data collection and more site-specific and refined modeling. For example, the IWAIR dispersion analysis does not consider wind direction in estimating receptor risks. But, at any given distance, true receptors may be present in only one direction. This type of site-specificity must be considered before making control recommendations. Similarly, in many cases, waste characterization and emissions should be further evaluated before evaluating controls, since emission models may greatly overestimate emissions.

3. **The Guidance recommends that facilities control particulate emissions from waste management units. As a result, IWAIR assumes that particulate emissions are negligible and are not included as part of the modeling. In addition, IWAIR only evaluates the direct inhalation risks. Is this adequate for the chemicals considered (when answering this question, please keep in mind that there is another model for the groundwater pathway)?**

- **AE:** Though clearly called out in the peer review charge, the EPA's decision to not address particulate emissions is not raised in the TBD. Including particulate emissions in IWAIR would greatly complicate the model because the semi-volatile compounds (a few like BaP and PCDDs probably should not have been included in the IWAIR list) generate indirect exposures by their entry into the soil and surface water compartments. This pathway could be added as a logical branch to IWAIR or could be treated as a stand-alone model. The latter is probably preferable because the processes of emission, deposition and subsequent exposure involve specific and different calculation approaches.

The issue reduces itself to whether or not EPA wishes to include semi-volatile organic compounds in IWAIR. If they are omitted, a fair amount of complication is avoided, and all organic compounds are assumed to be volatile. If they are included in a volatile emitted phase, IWAIR should include indirect pathways involving at least air-to-plant transfers. These transfers enter the human food chain through produce, and the agricultural food chain through forage, silage and grain. The dairy or beef animals, which consume these feeds, further bioconcentrate in the animal tissue products entering the human food chain. (See comment 17 for further measures needed to include semi-volatile compounds.)

- **DF:** Especially with the impending new regulations on PM2.5 (regulations were issued last year but subsequently enjoined by the DC Circuit court) I question if this is adequate. I am not sure if it is possible for particulate material of aerodynamic diameter less than 2.5 micrometers to either be directly emitted or to form through photochemical and or aqueous phase atmospheric chemical reactions from emissions from these waste facilities. If it is possible, which seems likely to me, should not this risk to health also be evaluated as part of this assessment? I would think it should and profiles for these particulate emissions should be developed. I should point out that this is potentially a very major task. Thus, it could be the subject for further releases of updates to this model, rather than holding up release of this version. This seems especially appropriate, as the issue of the standard is still to be resolved legally.

- **CM:** By neglecting particulate matter emissions, the IWAIR model may be missing a significant portion of the risk, especially with respect to nearby offsite receptors. Significant potential particulate matter emission sources include wind erosion from undisturbed soils and waste handling activities. Other significant potential particulate matter emission sources include soil or waste storage piles which tend to dry out relatively quickly and are situated above the soil surface and thus exposed to higher wind velocities. In addition, movement of waste material via conveyor belts and drops to storage piles can also result in significant particulate matter emissions. These emissions, in some cases, may result in the majority of exposure to semivolatiles adsorbed to the waste organic carbon or the exposure to nonvolatiles (e.g., metals). At the present time, emission models for these types of sources can be found as empirical models in the *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, and Supplements (AP-42)*, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1985. It should be understood, however, that use of many of these models requires choosing justifiable default values for input parameters or requires the model user to input site-specific data. Selection of justifiable default values for these types of input parameters would not be a simple matter and could significantly increase the complexity of constructing particulate matter emission algorithms for the IWAIR model. Presently, the IWAIR model does not estimate particulate matter emissions because these emissions are assumed to be controlled. It has been my experience at both Superfund and RCRA sites that this assumption is not always valid. Indeed, fugitive particulate matter emissions from waste handling and processing may exceed the controlled emissions from the WMU.

- **AS:** If particulate emissions are truly controlled and minimized by WMUs, then the "no particulate emission" assumption is appropriate. It is certainly conceivable that landfills or land application units might release fugitive dust containing chemicals. In my recent experience assessing inhalation exposures to fugitive dust from soils at CERCLA sites, this pathway has not contributed significantly to risk. In general, from surface impoundments and land application units especially, I would expect volatile emissions to be a greater concern than particulates. Therefore, the emphasis on volatile emissions in this model is appropriate, especially with the explicit assumption that particulate emissions are adequately controlled. Nothing precludes the investigator from exploring risks from particulate emissions as a special case, albeit with a different model, should this pathway be a concern.

  However, given that this model assumes that particulate emissions are negligible, the list of chemicals considered by IWAIR includes some barely volatile compounds. Compounds with very low vapor pressures (for oily wastes) and very low Henry's Law Constants (for aqueous wastes) would be expected to have very low vapor emissions from any of the WMU types considered by IWAIR. Examples of some of these compounds include benzo(a)pyrene, 7,12-dimethylbenz(a)anthracene, phthalic anhydride, and benzidine. These compounds would be much more likely to be associated with particulate emissions than vapor emissions. It appears that toxicity of chemicals may have been considered without regard to chemical volatility in developing the list of chemicals included in the IWAIR database. Regardless of toxicity, nonvolatile compounds would be expected to pose little risk.

II. Specific Model Features

4. Does the flexibility to change emissions rates, dispersion factors, and toxicity benchmarks make a more robust tool or diminish the accuracy of the results? Explain why. Are there other parameters in the model that the user should have the ability to override?

- **AE:** The degree of flexibility with respect to options for user intervention is just about right. Too many more would be confusing, and fewer would unduly limit the model's versatility. I'm still wondering what values have been assigned as default dispersion factors are. This procedure is not documented in the TBD. No notice of them ever appears in the model screens.

- **DF:** a) The flexibility to change these factors, adds to the model capability and improves its final accuracy, assuming that competent and knowledgeable professionals apply the model. b) First, I have already stated that on-site meteorology would improve model accuracy. Second, on Screen 5B, when the user identifies dispersion factors, the user should also enter the receptor(s) distance(s) appropriate for the entered factors. At present, the model specifies only the specific pre-selected values (25, 50, 75, 150 and 1,000 meters) that cannot be changed. The user who will be exercising an air quality dispersion model to generate these coefficients, should be allowed to enter appropriate receptor distances. When the user enters "override" dispersion factors they will be calculated for specific receptors, the user should be able to input these receptor distances. This can represent a small check on the user who is entering dispersion factors to ensure that the user understands these represent a specific place in space, i.e. a receptor distance.

  Third, I think this is a minor point, but the shape of the waste facilities and their orientation toward the wind appears to exert a significant influence on dispersion. Table D2 (b) shows that UAC values could be as much as 50% different depending upon waste configuration and its orientation at specific sites. Model developers, therefore, selected a square source to minimize errors because "..no data on source shape or orientation is [are] available.." . While, I doubt if it would be a major factor, a parameter to represent a correction to the UAC for waste shape and orientation with respect to on-site meteorology might be added. Perhaps, something like, multiplying the UAC by 1.5 if the longer dimension of the waste facility is greater than 2 times the shorter dimension and it is within + 30 degrees of the prevailing wind direction.
- **CM:** The ability of the user to change the emission rate, dispersion factors, and toxicity benchmarks definitely enhances the usability of the model. This, of course, assumes that any values entered by the user can be justified and evidenced by referenced calculations or with measured data that has been acquired using a proper quality assurance project plan. The correct use of referenced calculations for user-input values should in no way be trivialized. Even the most accepted mathematical models may be misapplied or simple calculation errors may give, in some cases, grossly inaccurate results. Allowing the user to enter his/her own values may increase the flexibility of the model but will require regulatory staff to verify all calculations and the appropriateness of input parameter values. This may impose a significant burden on the regulatory community.

- **AS:** The ability to change parameters in the model is a useful and necessary aspect of this model. This flexibility allows the user to best simulate reality, explore the sensitivity of results to ranges of parameter values and explore the impact of changes in the source that might be considered to control emissions. As with all models, input parameter values need to be selected knowledgeably.

5. **Is the modeling approach that relies on matching limited site-specific information to previously calculated dispersion factors a reasonable method to estimate dispersion of constituents from a unit? If not, how should dispersion be calculated for these waste management units if the model is to remain quick, easy to use, and not require an extensive amount of data?**

- **AE:** The generic approach to zoning off the contiguous 48 states seems to be appropriate as far as it goes. How about Hawaii, Alaska or Puerto Rico? Why are they missing?

- **DF:** Yes, it is. However, I have two suggestions that might improve model accuracy while still maintaining needed simplicity.

  I have some concern about the use of 29 meteorological data sets to represent their regions. We know that meteorology does not lend itself toward this sort of regional averaging. While, the spatial association that is done in the model may be useful as an initial approach, I suggest that an alternative method that could select a more representative meteorology be developed. My thought is that some sort of local meteorological data should be required. On-site is best, but a local meteorological station that has annual surface level wind distributions (wind rose) will suffice. The user could then input this local wind rose data and the model could search the 29 sets of meteorological data to find the one most like the input wind rose.

  Second, somewhat related to the local representative meteorological data issue above, the model documentation is clear in identifying that it is only applicable in areas of "simple" terrain. "Simple" terrain is more an exception than the rule and it might be helpful to add a conservative (over-predicting) default for terrain that is significant relative to, say the height of inversions or stable layers in the area. (This again might be determined from local or on-site meteorology) For this situation, a conservative "box" model, whose dimensions are defined by an estimate of stable layer height (perhaps 300 meters could be a default value) multiplied by an area. The dimensions of the area could be estimated by how far emissions might travel in a days time, multiplying the lowest end of the wind speed distribution (say average of the lowest 10% of a year of hourly wind speeds) times 24 hours. This volume (300 m x WS m/s x 24x360 s) then would be divided into the total emission of chemical in question in

24 hours to estimate a concentration. This concentration would be applied at whichever receptors lie within its boundaries. The resulting UAC could be applied 10% of the time in a typical year. This sort of a backstop to support the unlikely potential for terrain driven stagnant conditions increasing concentrations. I have not had sufficient time to evaluate the impact such a calculation might make on actual concentrations. It is possible that it will not substantially change outcomes. Even if concentrations are an order of magnitude higher, for 10% of the year (I estimate an order of magnitude, 10% of the time, would be an upper limit on how much concentration could increase) the result will only double the UAC. From the model calculations that I ran, this is not likely to have a significant effect in most cases.

Finally, a third point, by fixing receptor distances, maximum ground level concentrations are not necessarily calculated. This is not likely to be significant except in the case of the elevated source waste pile emissions where the fixed receptor distance could miss the maximum ground-level concentration.

- **AS:** For a first-cut, conservative estimate, the use of generic dispersion factors such as those embedded in the IWAIR model is reasonable. I make this statement with considerable reservation, since I fear that in many cases the results of such an analysis might severely overestimate risk. The matching of a regional meteorological station to represent the dispersion regime of every WMU in a geographical area is fraught with uncertainty. Local micrometeorology in the vicinity of a facility can differ vastly from that measured at a regional airport. The lack of directionality in the IWAIR analysis may also lead to overly conservative results in many cases. There is probably more variability in the predicted concentrations at a given distance from a source by direction, than there is among the maximum predicted concentrations at each distance among the 29 meteorological stations included in the IWAIR database.

  The geographical matching may give some users the impression of greater accuracy than is warranted. The difference between the highest and lowest UACs among stations listed in Tables 3-4 and 3-5, for instance, is only a factor of 2. This difference is small in comparison to the uncertainties inherent in (1) the emission estimates generated by models such as CHEMDAT8, and (2) the toxicity benchmarks used in risk analysis. Given these facts, I would recommend considering using a single, conservative dispersion factor based on a statistical analysis of the highest UACs from each of the 29 meteorological stations (or more stations could be used). The upper 90% confidence limit about the mean of these values would be an appropriate, conservative estimator. Use of such a single value for all locations would give conservative results without giving the impression of location-specific accuracy for the results of these screening analyses.

Alternatively, I would like to see a comparison of windroses from each of the 29 "regional" meteorological stations to each of the other major reporting stations in each region, to get a better sense of (1) the representativeness of the selected stations, and (2) the actual variability among the stations by region.

6. Are the number of representative meteorological stations sufficient for assigning previously calculated dispersion factors? If not, how many should be added and where?

- **AE:** Pardon my provincialism, but some thought might be given to more coastal representation. For example there are a lot of New England coastal areas represented by Hartford, which has a distinctly inland valley climatology.

- **DF:** I think that, with the addition of the Box model mentioned above, the number is sufficient.

- **AS:** As indicated to my response to Question No. 5, I am skeptical about the accuracy of assigning any of the "representative" meteorological stations to any other location. I like the approach of running ISC3ST to develop dispersion factors. The Soil Screening Levels study document (EQM and Pechan, 1993) reportedly claimed that the 29 meteorological stations predicted mean dispersion from a population of 200 stations with 95% confidence. Assuming this statement is correct (I have not reviewed the original study report and cannot independently corroborate), then the 29 stations used are probably adequate.

7. Are the assumptions made for the dispersion modeling appropriate (i.e., flat terrain, rural vs. urban, etc.)?

- **AE:** From a practical sense, one just about has to go with flat terrain to avoid the requirement of a digitized terrain database. These sources are surface based or low level; therefore terrain features will not be as prominent as in cases of elevated point sources. Nevertheless, there could be a screening of the zip codes or lat-long to put up warning signs for certain geographic locations in which the flat terrain assumption may not work. For example, a simple algorithm could compare the elevation of the receptor with the elevation of the source, using USGS digitized terrain data.

- **DF:** Yes, they are for the rural vs. urban dispersion coefficients. I have suggested a procedure that could deal with the terrain issue. Alternatively, a sensitivity analysis of terrain could be done to show that this sort of a calculation would not make any significant difference.

- **AS:** Yes. For a screening model, each of the above assumptions is appropriate in the absence of any site-specific information. The user may substitute dispersion factors developed external to IWAIR if complex terrain or urban environs are more appropriate. Since particulate emissions are not considered by IWAIR, wet and dry deposition should be negligible (particularly for a screening analysis).

8. Have the boundaries surrounding a meteorological station that assign a region to a station been assigned appropriately and with a reasonable methodology? Is there a better method for assigning facilities to a meteorological station?

- **AE:** See answer to 6.

- **DF:** a) I have above suggested an alternative approach. Using Bailey's ecoregions to help define specific boundaries for the 29 regions is creative and valuable. However, in many regions the diversity of meteorological observations can be just as large within one of these regions as across regions. I know that, for example, in the western regions, say the one represented by Denver, meteorological conditions are dramatically different based on the elevation and surrounding topography of the site. I believe the diversity of conditions in this region is as great as the diversity represented in all 29 of the selected stations. I have not had time to look at the EQM and Pechan, 1993 reference that is presented as a justification for representing the 200 Station's data available on EPA/SCRAM, but, even the SCRAM data set is quite limited in its representation of actual meteorological conditions. b) I think the method selected may be appropriate as a rough screening approach but this should be quantified somehow. One approach, provide information about how many of the 200 meteorological sites mentioned above are reasonably represented by their selected regional site. The model can be improved with addition of a provision that would allow a simple comparison of local meteorology with the representative station to determine if it is acceptably similar or not and an algorithm that could search the 29 meteorological data sets to determine the one that is most closely representative could be added. This is addressed earlier in answer to Question #1.

- **AS:** See response to Questions 5 and 6.

9. Is CHEMDAT8 an appropriate emissions model to use in IWAIR. Do you think that the emissions estimates calculated by CHEMDAT8 over predict, under predict, or provide a reasonable prediction of the emission rate from a unit?

- **AE:** For volatile chemicals, CHEMDAT8 may not cover certain pathways like droplet entrainment, accidental leaks and spills and fugitive emissions from waste handling equipment. For the pathways covered, CHEMDAT8 is probably satisfactory in that its assumptions net out to slight overestimates. For semi-volatile chemicals, the particulate issue could be an important source not covered by CHEMDAT8. (See answer to 3.)

- **DF:** I have no experience with CHEMDATA8 but it certainly seems to be the most appropriate source for emissions data. It has been widely reviewed and is well known in the community.

- **CM:** The emission calculations used in the IWAIR model are taken from EPA (1994). The calculations for active landfills, land application, and waste storage piles incorporate both evaporation of the liquid phase contaminant from the waste surface and diffusion of the contaminant through the porous medium of the waste. Surface evaporation is calculated depending on the averaging time over which the emissions occur. For short time periods, emissions from both surface evaporation and diffusion are calculated; for longer time periods, diffusion alone is considered. For surface impoundments (both quiescent and agitated), emissions are modeled as a function of the two resistance film theory. These calculations assume a well-mixed system with emissions dependent on chemical properties (e.g., Henry's law constant) and system properties (e.g., degree of surface agitation, windspeed, etc.).

  Using the equations in EPA (1994), I tried to duplicate the solutions to the emission rates predicted by the IWAIR model for each type of WMU. Except for emissions from surface impoundments, it was not possible to directly compare results in that the emission solutions provided by IWAIR are time-averaged values while the example problems given in EPA (1994) evaluate instantaneous emissions at a specified time. Given this constraint, I used a trapezoidal approximation of the integral to estimate the time-averaged emissions over the time of calculation (t_{calc}) as specified in the IWAIR TBD. Using this technique, same order of magnitude results were achieved with some comparisons within a factor of two. In addition, emissions based solely on diffusion were compared with other diffusion models; results were nearly identical. From the IWAIR TBD and User's Guide, it was not possible to determine exactly how emissions were integrated over time. For example, were the time-averaged emissions evaluated using a trapezoidal or Simpson Rule approximation of the integral? For contaminants in residual phase, were the mole fractions recalculated at the end of each time-step interval or were the mole fractions assumed to be constant with time? If the mole fractions are recalculated at each time-step, the relationship between waste concentration and equilibrium vapor concentration is not linear with time. If indeed the change in the mole fractions are accounted for in the emission calculations, this would explain why the Newton-Raphson method was used to evaluate risk as a function of waste concentration.

I found the explanations and the discussions of the relevant equations in EPA (1994) to be rather difficult to follow. It should be expected that someone with limited experience with emission modeling would have a considerable degree of difficulty understanding not only the theory but the hierarchical procedures required to derive a solution to the emission calculations. To help reduce potential confusion, my recommendation would be to include the appropriate sections of EPA (1994) within the IWAIR TBD. These sections, however, should be rewritten in a sequential order with a minimum of theory; the IWAIR TBD could refer the user to EPA (1994) for a more thorough explanation of the theoretical considerations.

The following represent questions the answers to which were not apparent in either EPA (1994) or in the IWAIR TBD or the User's Guide.

- According to the modeling assumptions in the IWAIR TBD, biodegradation is modeled for all emission sources except active landfills. In EPA (1994), however, biodegradation is not modeled for waste piles because no significant biomass is presumed to be available. In addition, the waste is assumed to be toxic to any potential biomass. An explanation of this apparent discrepancy could not be found in the IWAIR TBD.

- On page 8-40 of EPA (1994), the waste pile is assumed to be flat with a uniform height of 100 cm (1 m). This is consistent with the emission model geometry of a flat infinitely deep slab emission source as described on page 7-4 of EPA (1994). It is not clear in the IWAIR documents whether this is also the assumed pile height for purposes of estimating emissions in that the model asks for both the pile height and area. For the purposes of dispersion, waste piles are evidently modeled as elevated area sources with heights above grade of either 2 or 5 meters. Because the model asks the user for both the area and height of the waste pile, it should be made clear what geometry is used for both emissions estimation and dispersion. When I came to this section of the model, my first assumption was that a storage pile was configured as a right cone, not a flat slab. This potential for confusion concerning pile geometry could be eliminated with an explanation in the IWAIR TBD.

- It is not clear in the IWAIR documentation how the time-averaged fraction emitted to air is calculated. It is assumed that the instantaneous fraction emitted to air at time = t for active landfills, waste piles, and land application is calculated with the appropriate equations from Table 7-3 of EPA (1994) depending on the values of $K_v t$, F_a, $K_v t_b$, and $K_d t_b$. To estimate the time-averaged emission rate or fraction emitted to air, the instantaneous emissions must be integrated from time = 0 to time = t. Because a numerical estimation of the integral is evidently employed, an explanation of the numerical technique used should be given in the IWAIR TBD.

- It is clear in the IWAIR TBD that the windspeed and temperature data retrieved by the model for the applicable meteorological station represent annual average values. It is presumed that the windspeed is used in calculating the gas phase mass transfer coefficient and that the temperature is used to calculate the contaminant vapor pressure assuming that the waste temperature has come to equilibrium with the ambient air temperature. If this is the case, it should be confirmed in the IWAIR TBD.

- The emission model for surface impoundments will not allow the user to enter initial aqueous contaminant concentrations greater than the solubility limit. It is therefore assumed that the model does not include algorithms for estimating emissions from oil film layers at the surface of the impoundment as specified in Section 5.7 of EPA (1994). It has been my experience that this situation is not uncommon. Not including oil film layer emission calculations seems to be a model shortcoming.

• **AS:** The emission sources being considered in IWAIR are extremely difficult to model accurately. Landfill and surface impoundment emission models in general consider a limited number of parameters in calculating emissions. These sources and their emission mechanisms can be very complex. My impression is that a limited amount of validation has been performed on these types of models, and the validation experiments represent a limited set of conditions that may not represent a source of this type at another time or under different meteorological conditions. Models such as CHEMDAT8, in my opinion, produce a scientific emissions guess.

  My impression of CHEMDAT8, based on technical papers I've seen, is that it tends to overestimate emissions. This overestimate may be quite large in some cases (an order of magnitude). In the handful of comparisons to other modeling approaches that I explored as part of this review, CHEMDAT8 always predicted higher emissions. CHEMDAT8 has the capability to produce estimates for the range of WMUs being considered by IWAIR; other available models may be able to only handle one type of WMU (such as landfills or wastewater units). Given its apparent conservatism and its ability to handle all WMU types, CHEMDAT8 is an appropriate screening tool. I recommend that the conservatism of CHEMDAT8 be emphasized in the IWAIR documentation, to discourage a false sense of accuracy for the estimates produced.

10. **Are there other tools or modeling approaches that would better serve the purpose of the location-adjusted analysis? If so, what are they?**

- **AE:** Subject to the limitations, which should be more clearly stated in the TBD, the choices of models and data serve the purpose of the location-adjusted analysis.

- **DF:** I think the most appropriate tools have been used. The only suggestion would be to do something like suggested above in answer to questions # 5 & 8.

- **AS:** For a screening-level assessment, the current approach used in IWAIR to infer location-specificity is probably as reasonable as any alternative. As discussed above, I am skeptical about the representativeness of data from a regional meteorological station for another location as far as 500 miles away. Given all the uncertainties of the dispersion analysis and the even greater uncertainties associated with the emissions and risk calculations, I recommend that EPA consider abandoning the location-specific concept altogether.

  A more accurate approach would be to use the nearest, appropriate and available meteorological dataset for each site, and consider wind direction and location of true receptors in estimation of risk. Obviously, this approach would require site-specific data collection and analysis for every site, and would be more resource-intensive than I believe EPA desires.

11. **ISCST3 is sensitive to the size of the area of the source. To obtain a dispersion factor for a specific waste management units surface area, an interpolation routine was used. Is this an appropriate method for estimating the dispersion for a specific surface area? Is there a better method?**

- **AE:** Judging from the ISC3 unit concentration output tables in the technical support document, I believe that interpolation among the different areas calculated is within the expected accuracy of the model.

- **DF:** Size of the unit is a critical parameter; however, the interpolation method being used seems to be appropriate. I think any more complex interpolation would not yield significantly different results.

- **AS:** The current IWAIR method for estimating dispersion factors for any surface area relies on linear interpolation between two areas with known dispersion factors (based on ISC3ST model runs). This approach has the advantage of being relatively simple, both for the user to understand and for the program to compute. Based on my visual analysis of a plot of UACs vs. Surface Areas for 2-meter high waste piles (Little Rock data), it appears that the linear interpolation may underestimate the UAC by up to 20% in some regions of the graph. For example, if one looks at Figure 3-6, page 3-16 in the Technical Background Document, it appears that the curve of the true line between the points at 10,000 m^2 and 100,000 m^2 would lie above the straight line that connects these points. I consider this amount of error to be small compared with other uncertainties of the IWAIR model.

I can suggest two better approaches. The first is to run ISC3ST for more areas to require less linear interpolation between adjacent size areas. The second is to apply the linear interpolation routine to the logarithms of the adjacent areas. This approach tends to equalize the distance between adjacent known points on the UAC vs. Area curve, and appears to reduce the error to about 10%. For the waste piles, this approach slightly overestimates emissions.

III. Parameters Used for WMUs

12. Comment on the assumptions and parameter ranges used for in the model that are shown on the attached tables (Tables 1-4). Are the assumptions appropriate for the type of analysis? Are the parameter ranges reasonable and reflective of the range of unit characteristics and conditions encountered in real situations?

- **DF:** They appear to be appropriate given the objectives of the IWAIR model.

- **CM:** In the case of diffusion-limited emissions, waste air-filled porosity is the most sensitive nonchemical-specific model parameter. The default values given in Tables 2-1, 2-2, and 2-3 of the IWAIR TBD assume that one half the total waste pore space is air-filled. This assumption seems relatively conservative which would be appropriate for a screening-level emission model. The default value of the degradation rate of total organics given in Table 2-4 of the IWAIR TBD is 19 mg/g. On page 7-38 of EPA (1994), the ratio of the aqueous biorate for benzene (19 mg VO/g biomass-h) is divided by the measured decay constant for benzene in clay loam soil of 0.034 day^{-1}; this results in a value of 0.00179. EPA (1994) goes on to say that the value of this ratio (0.00179) is used for all compounds to convert aqueous biorates to decay constants for use in the land treatment model. The decay constant (t_b) in units of seconds is thus calculated for any contaminant by: t_b = 86,400 s/day ÷ (0.00179 x B) where B is the biorate constant of the contaminant in units of mg VO/g biomass-h. It is assumed that the default degradation rate of total organics in Table 2-4 of the IWAIR TBD is the value for benzene but more accurately should be given in units of mg VO/g biomass-h. If this is the case, the value of 19 mg/g-h is at odds with the default biorate from page 7-40 of EPA (1994). Here the default value is given as 40 mg/g-h. Finally, the default value of the degradation rate is tied to an assumption that all possible wastes for land application (and thus waste piles) are similar to benzene in biodegradation potential. Some wastes, however, may not fit this assumption (e.g., halogenated wastes) and the toxicity of the contaminants relative to the biomass may be quite different.

13. **Comment on the default values shown on the attached tables (Tables 1-4) that are assigned to some of the key parameters. Do these defaults seem reasonable, would other default values be more appropriate? If so, what are they or where can the data be found to develop better defaults?**

- **DF:** Default values seem appropriate and reasonable. The only addition, I would suggest, is adding default limits on a number of the physical parameters associated with the size of the facility, e.g. Table 1 Total Area of Landfill set to size of the largest existing facility, Average annual quantity of waste, same idea, etc.

14. **Comment on the assumptions that were used in the dispersion modeling to develop the dispersion factors. Are these assumptions appropriate for developing dispersion factors around industrial facilities? If not, how should they be changed?**

- **DF:** a) As mentioned above, the assumptions about dispersion factors are appropriate with the possible exceptions noted. b) Suggestions involving use of on-site or local meteorology, an approximation for very stable conditions and a facility shape factor have been suggested above for consideration.

15. **The emissions calculation performed by CHEMDAT8 uses either Henry's law or Raoult's law depending on whether the waste is aqueous or oily. For oily (organic wastes), the model uses Raoult's law and the liquid-to-air partition coefficient becomes proportional to the contaminant's vapor pressure. For aqueous wastes, the model uses Henry's law and the liquid-to-air partition coefficient becomes proportional to the contaminants Henry's law coefficient. The rule of thumb used in assigning which way the waste will be modeled using IWAIR is dependent on the fraction of organics in the waste. Once the user has specified the constituents in the waste, IWAIR will estimate the fraction of organics. If the waste contains more than 10% organic material then the emissions are estimated using Raoult's law. Is this rule of thumb scientifically accurate? Is there a better method of choosing which way the emissions should be modeled?**

- **DF:** This is beyond my area of competence, although it seems reasonable, I cannot answer the question.

- **CM:** The IWAIR model assumes that the total organics in the waste are comprised of a set of relatively volatile constituents and another set of less volatile constituents. The model treats the latter as a single entity with a default molecular weight. This approach apparently is an extension of the assumption that the waste is either petroleum waste or an equivalent oily waste. If, however, the waste is comprised of only a few contaminants of relatively equal emission potential, the best way to determine the aqueous phase equilibria is by calculating the effective solubility of each contaminant. Concentrations above the effective solubility signify the presence of a residual phase and equilibrium vapor concentration would be calculated by Raoult's law; concentrations below the effective solubility require the use of the Henry's law constant. Phase equilibria in a porous medium such as in soil or solid waste is more complicated and requires a relatively sophisticated solution. The approach taken in the IWAIR model is appropriate for the types of wastes for which it was first applied (e.g., petroleum-based wastes and other oily wastes) but may not be applicable for all situations.

When a residual or pure component phase exists, the IWAIR model calculates the equilibrium vapor concentration as a function of the liquid mole fraction, the vapor pressure at temperature, and the molecular weight using Raoult's law and the ideal gas law. Over the time-averaging period, however, the model should consider changes in the mole fraction of each constituent as the more volatile components are emitted at a faster rate. At this time, I could not determine if the mole fractions are recalculated at each time-step. Regardless, calculation of the equilibrium vapor concentration at the transition point between the residual and aqueous phases can produce a very significant discontinuity. Numerical solutions to multicomponent phase equilibria which minimize this discontinuity exist but require much more sophisticated mathematical calculations. These calculations could be coded into Visual Basic for use in IWAIR, but would require considerable resources.

When waste concentrations are less than the solubility limit or less than approximately 10 percent total organics, the model calculates vapor equilibrium based on the Henry's law constant. Unlike residual phase equilibrium, the Henry's law constant is used only at standard conditions (25ºC and 1 atmosphere of pressure); no adjustment is made for system temperature. Correcting the Henry's law constant for temperature can have a significant effect on vapor equilibrium. Correcting for temperature has the greatest effect on semivolatiles. For example, reduction of the solid waste temperature from 25ºC to 10ºC reduces the Henry's law constant of benzene by about 50 percent; this same temperature change reduces the Henry's law constant of a typical semivolatile by perhaps one order of magnitude. Data could be included in the IWAIR model to make this adjustment. The required chemical-specific data includes the enthalpy of vaporization at the normal boiling point, the normal boiling point, the critical temperature, and the B and C Antoine coefficients.

16. **There are several checks in IWAIR designed to ensure that the parameters entered by a user are realistic. For example, IWAIR checks the tilling depth of a land application unit in relation to the depth of application that is calculated from inputs by the user. Please comment on all the checks in IWAIR. Do these checks capture unrealistic entries? If not, recommend an alternative.**

- **AE:** The checks built into the software seem adequate.

- **DF:** They seem appropriate; I have not found any that seem unrealistic.

- **CM:** It appears that the built-in checks ensure that the model captures unrealistic entries. I did, however, experience one problem. I entered ".5" and ".25" as values for total porosity and air-filled porosity, respectively. The following message was subsequently displayed: "Data type mismatch, e.g., text entered when number expected." After re-entering these values as "0.5" and "0.25", the same message reappeared. I could not eliminate this message without restarting IWAIR.

17. **IWAIR can model the risk for 95 constituents (volatiles, semi-volatiles, and mercury.) These are the chemicals that were selected by OSW to model in study, the Air Characteristic Study, that evaluated the potential direct inhalation risks from certain waste management units. The chemicals were selected for the Air Characteristics Study based on their potential to generate a risk via the inhalation pathway. Are there other chemicals that are commonly used in industry that should be added to the list of constituents considered in IWAIR?**

- **AE:** As mentioned elsewhere in this review, there seem to be several semi-volatile compounds represented on the list. This seems to raise some problems. If they are retained, the questions of particulates and of indirect pathways arise. Also, if you keep BaP and 2,3,7,8 TCDD, there are a whole host of relatives in their chemical families that do not appear on the IWAIR list, but for which fate data exist. In cases of both the PAHs and the PCDD/Fs it is likely that the omitted compounds will be at higher concentrations in typical wastes than the compounds on the list with the possible exception of naphthalene. In a model which professes to treat semi-volatile contaminants, certainly the members of the PCB family must be included. If the treatment of semi-volatile compounds is eliminated, some important sources of risk may be left out of the calculation. The agency must make a judgment call: include all of the semi-volatile compounds (including PCBs) along with additional significant pathways or take them out altogether without apology, but with the proviso that the model is intended for use with volatile compounds only. Mercury should be retained, but guidance on speciation must be provided because of differing toxicity (e.g., mercury, methyl mercury and divalent mercury). Surprisingly, IWAIR gives cancer risk output for mercury, but no non-cancer risk! This is counter to Table 5-1 which correctly shows that non-cancer, rather than cancer effects are the issue with mercury exposure. Also, with mercury, we run into the multimedia problems because of possibly some being on particles and because of possible indirect pathways. In this sense, the dilemma with mercury is similar to that with semi-volatile organic compounds.

If dioxins and furans are retained, carrying them in the liquid compartment at the solubility limit and assuming vapor after volatilization into the air pathway is valid for the conditions of interest to the model user. (All bets are off, however, if these compounds already are adsorbed to fugitive dust particles). Several years ago we examined the problem of dioxin vapor to particle ratios in plumes. We found that once the plume reached ambient conditions of temperature and particle loading, the times characterizing the condensation of vapor on particle surfaces were long compared with residence times in urban areas. Thus, I would support the modelers' assumption of once emitted as vapor, the dioxins remaining in vapor phase until they reach receptors located a few hundred meters away. Below is an order of magnitude calculations supporting the exclusion of condensation of dioxins and furans on pre-existing particulate matter in the air.

Three assumptions define a bounding calculation for depletion of vapor by condensation on particle surfaces:

1. Every dioxin molecule that reaches the particle surface sticks to that surface
2. Any migration of dioxins to particles does not reduce the vapor phase concentration
3. The instantaneous surface concentration of dioxin molecules is always zero

The last two assumptions violate the conservation of mass in favor of health conservatism, but we are trying to calculate a bound, not an exposure.

The mass transfer to a surface is defined by a mass transfer coefficient k defined by

$$k = \frac{\mathit{Flux}}{(c_1 - c_o)}$$

where c_1 is the average mass concentration of dioxin vapors in the air parcel and c_o is the concentration of dioxins immediately adjacent to the particle which we set equal to zero to maximize the flux. The mass transfer coefficient for particles that move at air velocity is given by k=D/r (see for example Seinfeld, J.H., 1986: *Atmospheric Chemistry and Physics of Air Pollution*, Wiley-Interscience, New York, p.267) where D is the diffusion coefficient of dioxins in air (taken to be 5E-02 cm^2/s) and r is the particle radius (taken to be 5µm to represent particles presenting large surface areas). The particulate concentration χ is assigned the value of $100\mu g/m^3$; another value chosen to maximize available surface area. If the density of the particle mass is ρ_p, then the number of particles per unit volume of air is $3\chi/4\rho_p\pi r^3$ and the surface area of particles per unit volume is $3\chi/4\rho_p r$. Let us assume that the wind is blowing at 3 m/s so that the flight time of the average air parcel from the disposal facility to the receptor that is 300m downwind is 100 s. Applying the definition of the mass transfer coefficient given above, we get a fractional change in vapor concentration over this time interval to be given by

$$\frac{\Delta c_1}{c_1} = \frac{3D\chi t}{\rho_p r^2}$$

Substituting the values designated in the narrative above we find that $\Delta c_1/c_1$ is only 0.003, which is a negligible fraction attaching to particles even under the extreme limiting assumptions adopted. Therefore, the assumption of all vapor phase dioxins out to the receptor is a reasonable approximation of reality if the dioxin enters the air in the vapor phase.

- **DF:** As mentioned above, the only additional constituents that might be worth considering are particulate matter smaller than 2.5 micrometers in diameter. These can be generated in the atmosphere associated with VOC emissions or, I assume, could be directly emitted from the waste facility. Further, they might be so small that they would not be controlled by conventional particulate controls required for the facility. I am not an expert in this area so it might be appropriate to get an opinion from someone who is.

IV. Risk Assessment

18. IWAIR will calculate the additive risk from the carcinogens. Considering additive risk for non-carcinogens is more uncertain due to target organ or multiple organs effects. Should a means for adding together the non-carcinogens be added to IWAIR? If so, please suggest a method.

- **AE:** No, the non-cancer risks should not be additive if they represent different end-points; however, it is useful to display in the output the sum of the health hazard quotients (sometimes called the health hazard index) for screening purposes. The idea of screening is if the totality of health hazard quotients is far less than one, there is no need to break it down further. Both the component and total values should be displayed on the screen with a footnote about screening. Subtotals for like endpoints are also appropriate; for example, if chemicals A, B and C all cause upper airway irritation, it is logical to add their health hazard quotients.

- **DF:** This question is outside my area of expertise; I am not qualified to answer it.

19. Are the risks appropriately characterized for the cancer and non-cancer risks?

- **AE:** Under the restriction to volatile compounds acting only through the inhalation pathway, the risks are appropriately characterized. There are, however, some questions that need answering along the way in the risk calculation. See specific comments for these questions.

- **DF:** This question is outside my area of expertise; I am not qualified to answer it.

- **AS:** I checked the calculations of Cancer Risk and Hazard Quotient in several IWAIR model runs. I was able to duplicate the Hazard Quotient calculation, but always calculated different cancer risks.

  For cancer risks, I used data in the printed model output to check the risk calculations, following Equations 6-1 and 6-2 on page 6-1 of the Technical Background Document. In each case, I evaluated a resident receptor. I calculated the summation term in Equation 6-2 [sum (IR_I x ED_I / BW_I)] from the values in Table 4-1 (page 4-2) of the Technical Background Document to be 9.07 m^3-yr/kg-d. In both cases evaluated (vinyl chloride from a landfill and benzene from a surface impoundment), my calculated value was 9.2 times the IWAIR-produced risk value. There appears to be an error in the cancer risk calculations performed by IWAIR. A detailed explanation of these calculations and related model run reports are provided in Attachment A. (Comment: See Art Schatz's Check of IWAIR Carcinogenic Risk Calculation at the end of this section and Attachment A to his detailed write-up in Appendix C to this report.)

  I have also noticed that in seemingly duplicate model runs, IWAIR has sometimes produced different risk results. I can't explain these results, but suggest that the model calculation code be reviewed for bugs. (Comment: See Art Schatz's detailed write-up in Appendix C to this report for examples of IWAIR model output.)

  The printed IWAIR results report documents the waste concentration, emission rate, dispersion factor and final risk results. However, the exposure concentration in air (µg/ m^3) is never printed. This would be valuable information to provide the user.

20. Review and comment on the Newton-Raphson Method used in the back calculation approach in IWAIR. This information is contained in Section 6 of the Technical Background Document.

- **AE:** The Newton-Raphson Method is applied to the determination of roots of coupled simultaneous nonlinear algebraic equations. It uses the first term in the Taylor expansion of the equation to estimate the next trial for determining the root. One of its chief applications is the solution of chemical equilibrium compositions of multi-component systems. In the application presented in the IWAIR technical background document, it is really difficult to see why the program needs to use this method. First of all, the equations are linear, and second of all, the needed factors are all pre-calculated by the software. At first, I thought that maybe the unit concentration calculation introduced some nonlinearity, but that factor is calculated in a straightforward manner from the definition of the scenario. Likewise, the CHEMDAT8 output in the emissions screen is linearly dependent on the waste concentration so that, again, straightforward calculation is possible without iteration. For example consider the coupling between Eq. 6-4 and 6-9. Specifying acceptable risk, we can use 6-4 directly to obtain Cair. Then, moving along to 6-9, we can solve out for Cw from knowledge of Cair, Eunit and DF. The first of these three came from 6-4, and the latter two factors are generated on screens prior to the inverse calculation. Maybe I am missing something, but it would appear as if Newton-Raphson is not necessary. It causes the only noticeable pause in the execution of the program, so its elimination would be welcomed if this were possible.

- **DF:** Going backward from an acceptable risk to determine allowable loading, is a less determinate problem than the forward calculation, because waste can be partitioned in the aqueous phase (in soil water) or if above the soil saturation limit, in the oily phase. Simply doing the calculation can result in physically unrealistic results. To ensure this does not happen, a conventional iterative tool to locate the value of a numerically defined function of a parameter assumes at a particular value of that parameter. The numerical method (the Newton-Raphson method) is conventionally used for this sort of application.

- **CM:** If the air concentration is directly proportional to the initial waste concentration, the relationship between risk and waste concentration is linear. This is true if the waste concentration is below saturation (i.e., the solubility limit or saturation in soil/waste). This is not true, however, if the waste concentration represents a residual phase. In this case, the mole fraction of each constituent is variable with time and the relationship is nonlinear. If the relationship is nonlinear, the Newton-Raphson method is a reasonable approach for estimating the relationship between air concentration and waste concentration.

V. Quality of Software and Documentation

21. Comment on the ease-of-use and logic of IWAIR.

- **AE:** Generally, the user documentation is adequate. When I tried to install the software, it refused to load on the D:\ drive, my CD ROM drive. I discovered that the CD ROM had an embedded virtual E:\-drive on it. Once I prompted it to load on E:\ everything worked fine. This is a bit esoteric for the entry level user, don't you agree? Perhaps this could be fixed. Also, a help function with a library of backup screens would be essential for the beginner. The setting of receptor distances seemed awkward with all of the little pull down menus. Maybe it would be better to have a big array where you could just click on the values you wanted. As mentioned above, the whole notion of default receptor parameters is a bit mysterious. Are the default directions with distances preset? See further comments below.

- **DF:** It is appropriate for the audience intended. The model is very easy to use, its logic is well identified and appropriate given the objectives of for its design.

- **CM:** The IWAIR model is easy to use and logical in its presentation and sequence.

- **AS:** In general, I found IWAIR easy to use. The flow from location selection to WMU description, chemical selection, emission calculation, dispersion calculation, and risk calculation is logical.

22. Comment on the nature of the instructions within the program. Are they clear and easy to understand?

- **DF:** They are clear and easily understood.

- **CM:** The instructions in the program are clear and easy to understand.

- **AS:** I found the instructions within the program easy to follow. However, I am very familiar with each step of the modeling process. I would expect that some users would find some of the parameters required to run CHEMDAT8 unfamiliar and difficult to estimate. For example, in the case of an aerated surface impoundment, such parameters include Submerged Air Flow, Active Biomass, and Power Input to the Aerators. Also, the requirement to express all input parameters in metric units might hinder some users or lead to errors.

23. Comment on the layout of the user-interface screens. Are all easy to use and read?

- **DF:** All are easy to use and are well laid out. I would suggest adding a dialog box associated with the Screen 1 selection of the nature of the Waste Management Units. Upon selection of one of the three options a box could pop up indicating the sort of information about each that is contained on page 3-2 and the box on page 3-3 in the

User's Guide.

- **CM:** All of the user-interface screens are easy to use and read.

- **AS:** I found the layout to be easy to use and read.

24. Comment on the presentation of results. Are they consistent and easy to understand?

- **DF:** Results are presented clearly and are easily understood. I identified a typographical error on the Results screen (Screen 6), if one seeks to enter alternative health benchmarks, the dialog box that pops up has health spelled incorrectly.

- **CM:** The presentation of modeling results are consistent and easy to understand.

- **AS:** The results are reasonably easy to follow, although sometimes extraneous or incorrect information is reported (see comments on case examples run). I like the general format of the printed output, but found the requirement to continually re-enter certain information on sequential model runs cumbersome. The results screen needs a simple "Print" button.

25. Comment on the ease of installation and file manipulation (saving and retrieval?)

- **DF:** Installation was very easy to accomplish; it only takes few seconds. Instructions are clear and straightforward even for someone not accustomed to lading new programs.

- **CM:** Model installation and file manipulation are simple.

- **AS:** IWAIR was easy to install. I had no problems saving and retrieving files.

26. Comment on the logic and clarity of the documentation. Were any important points, assumptions missing or inadequately explained?

- **DF:** Documentation is logical and straightforward. I did not notice anything that was missing or inadequately explained.

- **CM:** See the answers to Question 9.

- **AS:** I found both the Technical Background Document and the User's Guide to be generally well organized and easy to follow. I noted a few inconsistencies, missing pieces of information or errors, as listed below:

Technical Background Document

- Page 3-5, 1st paragraph. The last sentence says there are windroses in Appendix B. No windroses appear in the Appendix.

- Page 3-5, 4th and 5th paragraphs. These paragraphs will be difficult for most readers to understand. Technical references to Thiessen polygons, Bailey's ecoregions and conflation will be foreign to most readers. A simpler explanation of what was done is needed.

- Page 4-3, Section 4.3. The need for body weights for adults age 19-29 is specified twice. The reason that this age range is important for the model needs to be explained.

- Appendix D. This appendix discusses the sensitivity of ISC to the depletion option, source shape and orientation, and receptor location and spacing. While some of this discussion may inform and reassure some users, I found this to be level of analysis for these options to be misplaced. First of all, depletion is practically irrelevant for near-field dispersion of vapors – I found this discussion unnecessary. Source shape clearly influences area source emissions. So, for a simple screening model designed to fit many types of sources, a square area is an obvious neutral choice. I am much more concerned about misapplication of a "regional" meteorological data set to a particular source, and the effect of wind direction (which is totally ignored in this discussion), than any of these other factors that are covered in detail.

User's Guide

- Page 3-3. Text box with IWAIR Assumptions. Under Landfill Assumptions, the first bullet states that the active cell is modeled as being open for one year. This contradicts the Technical Background Document, page 2-9, which states that the active cell is modeled as open for t_{life}/N years. I believe the Background Document is correct.

- Pages 4-2 through 4-5, Figures 4-1 through 4-4. The headings of each text box need to be corrected so all letters appear.

27. Comment on the structure of the user's guide. Is it easy to follow? Are there any inconsistencies with the software?

- **DF:** In general, the User's Guide is well structured, it is easily read and understood. I found no inconsistencies in the software. However, one area I found that could be improved is Section 6, Example Calculations. While this section provides a sort of simple example of how the calculation is conducted, it does not lead one through a detailed calculation referring to the software. For example, it does not include any discussion of the selection of data required for inputs to Screen 3A,B,C or D. For the example, Screen 3B must be completed but only one of the required parameter values (Landfill surface area) is specified. I found these two examples to be confusing because of this and less than helpful.

- **CM:** The User's Guide is relatively easy to follow; I could find no inconsistencies with the software.

28. Comment on the readability of the user's guide. Can it be used by an individual without a lot of air modeling experience including members of the general public?

- **DF:** In my opinion, the user's guide is easily readable. Someone unfamiliar with air quality modeling can understand it.

- **CM:** As to whether or not the information and procedures in the User' Guide can be understood and followed by the general public, my first reaction is yes, however, this initial reaction is subjective. Perhaps testing the model with a representative sample of people would be useful.

29. Comment on the structure of the Technical Background Document. Is the modeling approach and logic used for development clear?

- **DF:** The Technical Background Document is easily read and easily understood. The modeling and its logic are clearly presented.

- **CM:** As stated in the response to Question 9, the TBD does not include the theoretical basis for the emission calculations nor the actual equations used by the model. I think it might be useful to include at least the appropriate equations from EPA (1994) within the TBD and refer the user to EPA (1994) for a more detailed discussion of the theory behind the emission algorithms.

30. Is there sufficient explanation concerning the structure and assumptions in the model? What else should be described?

- **DF:** I think there is sufficient explanation of the approach and do not think any additional explanation is needed.

- **CM:** All of the assumptions and limitations of each emission model should be included in the TBD. For example, none of the emission models deplete the emission source over time, i.e., the initial mass of contaminant is not reduced. Diffusion-based models do, however, account for reduced emissions as a function of time due to the increased diffusion path length. It is important for the user to understand model assumptions and limitations to be able to better apply the IWAIR model to site-specific conditions. I think it would also be helpful to the user to understand the relative uncertainty and sensitivity of individual model input parameters. This could be done by including a table for each model with a column for relative uncertainty (e.g., high, medium, low) as well as a similar column for model parameter sensitivity. In addition, a table might be included that shows the effect of changes in individual input parameter values as they relate to final incremental cancer risk or hazard quotient. This would give the user an idea of the results of using input parameter values other than the default values.

31. Comment on the readability of the Technical Background Document. Is it written at a level appropriate for someone with some environmental training and modeling experience?

- **DF:** The Technical Background Document is written at an appropriate level. It is appropriate for someone with an environmental background and some familiarity with environmental modeling.

- **CM:** The TBD is well written and suitable for someone with limited environmental training and modeling experience.

<u>Additional Responses from Peer Reviewers</u>

AE: Introduction

The development of IWAIR is a useful embodiment of two off-the-shelf EPA models, which have enjoyed widespread application in the past. The software implementation of the scheme works smoothly and has very few glitches. The software scheme is relatively transparent, and its documentation is accordingly clear in its linear presentation of model operation. For a significant range of applications the model should be useful for the purposes guiding its design. This review addresses a series of areas where improvements are possible in the documentation or the model design. There are places where good judgment has been exercised, and there are other places where some improvements are indicated. Before presenting the review, it may be helpful to outline the organization of the review in these introductory remarks.

AE: Improvements in Style of Presentation

The IWAIR model software synthesizes the algorithms and specific calculations from other pre-existing models. This places a special responsibilities on the author of the technical background documentation; namely, to provide an independent stand-alone description of each component model that is embedded in IWAIR, to present clearly and completely the assumptions in and limitations of each predecessor model and to convince the reader that the capabilities of the component models are appropriate for the IWAIR application. The document attempts to fulfill these goals, but the result is rather uneven. Some of the introductory material is clear, but other discussions are either unnecessarily abbreviated or absent altogether. All this having been said, it is the belief of this reviewer that the technical report should undergo some changes in its style of presentation in order to achieve its stated objectives. First and foremost it is essential in the rewrite process to retain a professional publications editor who will play the role of devil's advocate. This is the single most constructive comment than can be offered on behalf of achieving the objectives and repairing the problems enumerated elsewhere in this review. Such detailed assistance is beyond the scope of this review.

AE: Improvements in Technical Content

An executive summary added to each of the two documents (User's Guide and Technical Background Document (TBD)) will aid in relating the technical elements of the presentation and will provide a clear overview of the content from beginning to end. This section should clearly state in one to five pages the objectives of the document; why the work was done and what is hoped to be its application. Some of the background in the present "Introduction" more properly belongs in the executive summary. Furthermore, it should summarize the technical approaches without going into detailed descriptions. The general conclusions or applicability of the work should appear at the end of the executive summary.

The introduction of the technical work reported will benefit from expanding on one of the recognized steps in health risk assessment; namely, hazard identification. This would clarify the reasoning governing the choices of substances and pathways. In addition, this will provide the opportunity to present a simplistic screening analysis that combines contamination levels with threats to human health. Without this information, one might guess that the list was assembled from what could be found easily in the literature. Descriptions of approaches are generally thorough; however, lapses occasionally leave the reader wondering just what was done or what is really going on. Specific citations below back up all of these general observations.

The appendices form a nice compendium of information, but they deserve more discussion in the main text link them with the technical goals of the documentation. For example, no particular value judgments seem to be forthcoming after the extensive presentation of sensitivity studies of ISC3 in Appendix D of the TBD. Moreover, CHEMDAT8, the other cornerstone model, seems to have escaped the same degree of scrutiny afforded ISC3. Specifically, the report fails to present sensitivity studies of CHEMDAT8 (e.g., to data uncertainties) despite the fact that its reliability is equally crucial to the success of IWAIR. Either the dispersion model sensitivity studies should be omitted or the CHEMDAT8 sensitivity studies added.

AE: Specific Comments on the TBD

- Title: Will there be an industrial surface and ground water model? -- or a dust model? These pathways are not commented on in the reports.

- Sec. 1.1 needs to say up front that the model is only intended for inhalation of volatile organic substances and mention what is being done about the rest of the universe of waste contaminants. The word "organic" is an adjective, not a noun.

- CHEMDAT8 seems to be limited to steady state emissions by volatilization, and it appears to neglect biogas generation. In view of the numerous biodegradation rates given in the chemical tables, it seems strange that none of this biodegradation is allowed to result in gaseous products. In aerobic degradation carbon dioxide and water vapor seems to be the end of the line and in anaerobic processes, carbon dioxide and methane are produced. Where does all of the advection of these products come into the emission model? This looks like a violation of mass conservation. Clearly IWAIR admits biodegradation as a decay mechanism, then why not allow an option for major waste components to biodegrade? In so doing they decompose into simple molecules made up of carbon (methane and carbon dioxide), hydrogen (methane and water vapor), and oxygen (water vapor). The option would allow the user to enter gas generation potential and rate. In turn IWAIR would apply these data to calculate the biogas flow from the management facility. A partitioning calculation in the waste mass provides the toxic contaminant concentrations in the biogas flowing out to the atmosphere, and, hence, the advection-driven emissions of toxic organic compounds.

- At the bottom of p 2-11 it seems to say that the volume of the land treatment remains a constant in spite of new waste being added. As stated this seems to fly in the face of common sense. The issue of mass conservation is skirted by saying that what was there previously is eliminated from the problem by burying it deeper than before. Does this remove it from the problem as a contributor to emissions once it is beyond a certain depth? Based on the information provided in the TBD, it is not possible to determine exactly how IWAIR treats waste volume. EPA has models for buried waste that could be utilized for different burial times and different depths. Since they are linear, the solutions could be superposed. Obviously this is either inadequately explained or just plain wrong. As written it is not possible to judge.

- Eq 2-9 omits all the terms from n=1 to n=n-2, and the parenthetical factor multiplying the (n-1)st term further decreases the mass in place because the application depth is always less than the tilling depth. I believe the code does it correctly and that this is an inaccurate representation of what goes on -- especially in view of what Eq. 2-10 seems to say. These comments probably indicate a lack of understanding on my part; therefore, a careful rewrite of this section will assure the correct interpretation.

- Eq 2-11 implies that the fraction emitted is independent of the fraction biodegraded. Try to find a functional connection between these two. It probably exists, and it would be helpful in the conservation of mass.

- Section 3 and following passages alternate between "dispersion factors", "UACs" and "unit concentrations." This ambiguity in terminology is unnecessarily confusing. I prefer unit concentrations, but please pick one term and stay with it throughout the document and the program screens. How was the worst case chosen? What are "defaults"? How do the sixteen directions figure in? (they do not appear on the screens) What is the receptor geometry in terms of "squares"? This section needs the work of a good technical editor because it is really difficult to try to figure out what is going on as it is written. Refining the resolution of the receptor grid almost always turns up higher peak values. This seems to be almost treated as a discovery in this section.

- Page 3-3 Maybe it is not worth bothering to mention the undefined unreferenced "Dalenius-Hodges" procedure, if in the end, the spacing turns out to be arbitrary anyhow.

- Page 3-5 states "Large scale regional average conditions were used to select the actual stations". The reader deserves a few more sentences on what it was that (EQM and Pechan, 1993) did to help in this selection. Also, would it be possible to supply a definition of "conflation"?

- Beginning on page 3-11 the charts show a reassuring low degree of sensitivity of UAC to geographical location. Maybe I don't have to worry so much about coastal climatology as I did in a comment above in response to the charge questions.

- Page 4-1 Unnecessary confusion is caused by Table 4-1 because it seems to summarize some of the information provided in the rest of the tables in section 4. Then each of the subsequent tables has slightly different age stratification. This probably comes right out of the Exposure Factors Handbook, but the curious reader might like to know why these different categorizations exist among the tables. It might improve readability to replace the age stratified exposure parameters in the tables with a simple adult and child breakdown. As it stands, the age categories for the calculation do not coincide so that the interpretation of aggregate calculations becomes both confusing and inconsistent. In addition, the authors should provide an explanation of why central tendency exposure values were selected (as noted on page 4-1), even if they simple state that this is in keeping with standard EPA risk assessment practices.

- Section 5 second sentence reads:"Unit Risk Factors (URFs) and CSFs are used in the model for carcinogenic constituent regardless of the availability of an RfC." This is a non sequitur because RfCs could not replace either URFs or CSFs since they (RfCs) only apply to non-cancer end points.

- Appendix C is a nice write up of the toxicology profiles.

- Appendix D traces through the details of several sensitivity runs of the ISC3 dispersion model. There is no indication of what the author's error tolerance was, or how it influenced the choices of assumptions in IWAIR. Moreover, it is not explained why no sensitivity studies of CHEMDAT8 were undertaken.

DF: Summary

In conclusion, I believe the approach taken by EPA's Office of Solid Waste to characterize the health risks associated with volatile air emissions from industrial waste management facilities is sound. The approximations made in developing this model are appropriate to the purposes for which the model is designed. Although, I have suggested a few places where I believe the model could be improved, I am confident that it could be used in its present form for its intended applications. The suggestions I have made, therefore, might best be addressed in a later release or revision after a few years of practice with the current version.

CM: Overall Concerns

The following represent the major concerns identified in the draft version of the IWAIR model and documentation.

- From reviewing the documentation, it is my impression that the biodegradation algorithms rely primarily on empirical studies of municipal waste water treatment and treatment of petroleum related wastes. Biorate constants for individual contaminants may not be applicable for some industrial waste situations. High initial contaminant concentrations as well as the types of contaminants (e.g., halogenated compounds) that may be present in these systems may be toxic to naturally occurring bio-organisms or may require inoculation of the waste with specially engineered microbes. Therefore, the default chemical-specific biorate constants as well as the default biomass concentrations may not be applicable resulting in artificially high rates of removal. At the present time, the state-of-the science in regards to biodegradation is still evolving. The kinetics may or may not be first-order in nature for different contaminants and mixtures of contaminants. By relying solely on empirical data from a relatively narrow range of contaminants and bio-active processes, the degradation constants used by the IWAIR model may not be applicable for all industrial waste applications. See the response to Question 12.

- Equilibrium vapor concentration when a residual phase is present is based on Raoult's law and the ideal gas law. It is not clear in the IWAIR documentation as to whether the mole fractions are recalculated at each time-step of the emission models. In addition, the IWAIR documentation does not explain what procedure is used to calculate the time-averaged emissions (e.g., trapezoidal integration, Simpson Rule, etc.). If the change in the mole fractions are recalculated, this would explain the necessity for using the Newton-Raphson method for determining the nonlinear relationship between risk and waste concentration. The calculations need to be documented in the IWAIR TBD. See the responses to Questions 9 and 15.

- When applying Raoult's law to the calculation of the equilibrium vapor concentration, the vapor pressure of each contaminant is corrected for system temperature using the chemical's Antoine coefficients. The same cannot be said for the contaminant's Henry's law constant. Correction of the Henry's law constant for temperature requires a relatively simple calculation but also requires additional chemical properties data. Consideration should be given to including such a correction. See the response to Question 15.

- Documentation of the emission model equations, assumptions, and limitations are found in three separate documents. This can be confusing for the IWAIR model user, especially if the user has limited modeling experience. Consideration should be given to including at least the emission equations in the IWAIR TBD as well as the complete list of model assumptions and limitations. The sequence of equations used to calculate the emissions should be in the correct order without requiring the user to back-track through the sequence. See the responses to Questions 9 and 29.

- The emission model for surface impoundments does not include the equations in EPA (1994) for estimating emissions from oil film surfaces. These equations estimate emissions from residual phase contaminants floating on the surface of the impoundment. This is likely to occur for some industrial waste applications, therefore it would be prudent to include these algorithms in the IWAIR model. See the response to Question 9.

- All assumptions and limitations of each emission model should be included in the IWAIR TBD. In addition, consideration should be given to inclusion of simple tables for specifying the relative sensitivity and relative uncertainty of each model input parameter value. This would help the user to determine how the use of parameter values other than the default values would effect model outcomes. See the response to Question 30.

AS: Observations while running the IWAIR model

- **Selecting the meteorological station.** Once I've identified the appropriate meteorological station (by entering the zip code), I would like to be able to simply type in the name of the station in subsequent runs. It appears that the only options currently are to re-type the zip code or latitude/longitude coordinates. I also tried to pull down the map embedded in the program and click on the location of the station, but this doesn't work.

- **Model Output.** Model results can be printed from the "File" drop down menu, however, this option may not be obvious to the user. The ability of this model to generate a report at the end of each run is critical for documentation. A simple report-printing button should be added to the final screen. The ability to save the results as a file would also be useful.

- **Facility, Date, User and Additional Information Screen.** This screen, which pops up when the user selects the file - print option, documents useful information for each run. I like the way the data input screen is laid out, and the way this information is presented on the printed report. I suggest two improvements:

    - Allow this information to be saved from run to run, so it doesn't have to be re-input every time

- For the "Date of Sample Analysis", have an automatic default value with the current date, that can be overridden by the user as an option.

- **WMU for CHEMDAT8 screen.** On the WMU for CHEMDAT8 screen, temperature and windspeed values shown should be characterized as " average values for the Met. Station selected ".

- **User Override of Emission Rate.** I ran a Surface Impoundment test case where I input my own emission rate and dispersion factor (user override of CHEMDAT8 and built-in dispersion factors). At each input screen, I was required to enter a justification for the User Override Values. On the printed report, the dispersion factor justification was copied, but the emission rate justification was missing.

- **Dimensional Units in Output.** There appear to be several errors in the units of various parameters as they are expressed on the printed output, as follows:

  - For a landfill model, the chemical concentration is printed as mg/Liter, rather than mg/kg.

  - The dispersion factor is printed as micrograms/m^3 per (gram/m^2-sec), rather than micrograms/m^3 per (microgram/m^2-sec).

AS: Case Examples

Landfill Emissions. I ran a prior landfill example for comparison with a landfill emission estimate done for an emission inventory at an industrial facility (pulp and paper mill). The emission inventory estimate was calculated using a method recommended in AP-42. I chose two compounds at random to model: ethylbenzene and vinyl chloride. The emission rate results from the two methods (IWAIR and AP-42) were somewhat different. IWAIR was more conservative (i.e., produced higher emission estimates), which may be appropriate for screening model. The specific factors that may contribute to the different results between these models were not evaluated for this example.

Example inputs:

Landfill area:	28,329 square meters (7 acres)
Lifetime:	2 years
Depth:	3 meters (a guess, actual unknown)
Number of cells:	24 (a guess, actual unknown)

Comparative results:

Compound	**IWAIR**	**AP-42**	**Ratio, IWAIR:AP-42**
Ethylbenzene	0.077 tons/yr	0.058 tons/yr	1.3
Vinyl Chloride	0.31 tons/yr	0.056 tons/yr	5.4

Problems for user:

- May be difficult to obtain landfill depth
- May be difficult to obtain number of cells

IWAIR model results are sensitive to the number of cells assumed. I compared example calculations where all variables were kept constant except the number of cells, which was varied between 24 and 12. The results for 24 cells were 1.4 times the 12-cell results. IWAIR assumes the entire mass of waste placed in each open cell is placed at the beginning of the interval. This assumption leads to the estimate of higher emissions for a greater number of cells (for a given mass of waste disposed).

Intuitively, I would expect a landfill with more cells to have lower emissions than one with fewer cells over the same time period. In the landfill with more cells, the cells have a smaller area and remain open for less time. Both of these factors should result in lower emissions. In all cases, the emission rate decreases with time as the chemical evaporates (IWAIR correctly models this aspect). So, if a cell remains open for two months, the emission rate is higher during the first month than the second month. If all of the waste is assumed to be placed in the cell at the beginning of the interval (as IWAIR does), then the average emission rate for a cell open for one month will be higher than the average emission rate for a cell open for two months.

The IWAIR assumption that all waste is placed in a cell at the beginning of the interval is unreasonable. If the capacity of a cell were filled on the first day of use, it would make sense to close the cell immediately and open a new cell for the next shipment of waste. A uniform disposal rate over the interval would be a more reasonable assumption. I believe that a landfill model with a uniform disposal rate would exhibit less sensitivity to the number of cells in the landfill.

Surface Impoundment Emissions. I ran a surface impoundment example for comparison with a prior emission estimate done for an open API separator at a petroleum refinery. The prior estimate was calculated several years ago using EPA's SIMS model. In both cases, 6 compounds were modeled: benzene, ethylbenzene, n-hexane, naphthalene, toluene and xylene. The emission rate results from IWAIR were always higher than the SIMS results, although they are similar models.

Example inputs:

Surface Impoundment area:	182 square meters
Depth:	3.65 meters
Annual loading of waste:	935,000 cubic meters/year

Comparative results:

Compound	**IWAIR**	**SIMS**	**Ratio, IWAIR:SIMS**
Benzene	2.6 tons/yr	1.8 tons/yr	1.4
Ethylbenzene	4.9 tons/yr	2.6 tons/yr	1.9
n-Hexane	10.3 tons/yr	9.4 tons/yr	1.1
Naphthalene	1.3 tons/yr	0.001 tons/yr	1300
Toluene	10.3 tons/yr	7.9 tons/yr	1.3
Xylene	20.7 tons/yr	10 tons/yr	2.1

One explanation for the difference between the two models' results is that SIMS considered the waste to be oily; emissions from a floating oil layer were calculated as a function of each chemical's vapor pressure (i.e., Raoult's Law). IWAIR does not have the capability to consider waste in a surface impoundment as "oily", so its emission estimates are all based on Henry's Law (appropriate for aqueous wastes). IWAIR should either include an "oily waste" option for surface impoundments, or the documentation should explain why the aqueous waste characterization is appropriate in all cases.

I found several problems or inconsistencies with the surface impoundment module during this one test case, as follows:

- No user option to characterize waste as oily or aqueous. If there is a floating oil layer, the Raoult's Law estimation method is probably more appropriate, even if the oily layer constitutes less than 10% of the waste.

- If oily wastes are to be considered, then the solubility limit in the program (based on aqueous solubility) needs to be modified. Solubility in the oily layer may exceed the aqueous solubility.

- I noted the following problems with the printed output from the model:

  - At the input screen, Total Organics into the WMU is requested in units of mg/L. In the printed output, this parameter is incorrectly shown with units of grams/liter.

  - The output shows parameters and values pertaining to aerated impoundments, even when the aerated option is not selected. It would be better to not list this irrelevant information.

Back Calculation Option. I ran a landfill scenario in both the forward and back calculation modes. I found that when I took the predicted protective concentrations from the back calculation (based on a 1E-06 cancer risk level) and used these values as input in a forward calculation, the correct cancer risks were calculated. While not an exhaustive evaluation, this suggests that the back calculation method is reasonably accurate. However, through this exercise I noted the following problems with the model output:

- When selecting the print option, after entering the facility information, IWAIR requires the user to go back and specify a target Hazard Quotient (HQ) value, even if the compound being modeled has no RfC (which was the case for the benzene example I ran). The user should not be required to enter this irrelevant information in order to print results. After entering an arbitrary HQ value, all of the previously entered facility information is lost and the user is required to re-enter it before printing.

- The back calculation output lists emission rate values for each compound as both aqueous and oily wastes. The meaning of these numbers is unclear, but they clearly are not the emission rates associated with the predicted protective concentrations, since they are constant for each receptor distance considered. In matched forward calculation examples, the emission rate varies with the input waste concentration, as expected. The emission rate values printed on the back calculation output either should be suppressed or explained.

- I ran a relatively nonvolatile carcinogen, benzo(a)pyrene, in one back calculation. On the final calculation screen, a pop-up box gave the message that the maximum possible waste concentration yields risks below the target level. However, the printed output does not contain this information. These type of results should be footnoted accordingly on the printed output.

ISC3ST Comparison. I ran ISC3ST with a 5-year Detroit, Michigan meteorological data set to compare dispersion factors with those programmed in IWAIR. The main reason for performing this analysis was to see how representative the IWAIR regional meteorological station (Chicago, IL) would be for a Detroit, MI case. I modeled a square area source with an area of 12,546 square meters, which is the same as one of the areas shown in Table 3-4 of the Technical Background Document. I placed receptors 25 meters from the edge of the area, in 16 directions, equally spaced around the area, to match the method used to develop the IWAIR dispersion factors. The emission rate modeled was 1 $\mu g/m^2$-s, to yield Unitize Air

Concentrations (UACs) directly comparable to those in Table 3-4 and the IWAIR output.

The highest 5-year average dispersion factor at any of the 16 modeled receptor locations was 2.15 $\mu g/m^3$ / $\mu g/s\text{-}m^2$. The IWAIR dispersion factor based on the Chicago station was 2.8 $\mu g/m^3$ / $\mu g/s\text{-}m^2$, which results in a 30% overestimate of risk. This degree of conservatism is reasonable for a screening model.

Table 3-4 of the Technical Background Document (page 3-11) shows the UAC for Chicago as 10.505 $\mu g/m^3$ / $\mu g/s\text{-}m^2$, which is 4 times the dispersion factor actually used by IWAIR. There appears to be a systematic error in Table 3-4.

AS: Check of IWAIR Carcinogenic Calculation and Example Iwair Model Runs (Appendix)

[Note: Art Schatz conducted a number of IWAIR runs and a hand calculation to test the model's performance. One set of these is presented below. Others can be found in Mr. Schatz's detailed write-up in Appendix C.]

Check of IWAIR Carcinogenic Risk Calculation
(addendum to comment on Question #19)

Page 6-1 of the IWAIR Technical Background Document describes the method used by IWAIR to calculate air concentrations and cancer risks. The following two equations are used:

Eq. 6-1 Cairj = Ej x 1,000,000 x DF

where:

Cairj = air concentration of chemical j (ug/m3)

E = volatile emission rate of chemical j (g/m2-s)

DF = dispersion factor ([ug/m3] / [ug/m2-s])

Eq. 6-2 Riskj = (Cairj x 0.001 x CSFj x EF / (AT x 365)) x sum (IRi x EDi / BWi)

where:

Riskj = individual risk for chemical j (unitless)

Cairj = air concentration for chemical j ([µg/m 3])

CSFj = cancer slope factor for chemical j (per mg/kg-d)

i = index on age group (e.g., <1 yr, 1-5 yr, 6-11 yr, 12-19 yr, adult)

IRi = inhalation rate for age group i (m 3 /d)

EDi = exposure duration for age group i (yr)

EF = exposure frequency (d/yr)

BWi = body weight for age group i (kg)

AT = averaging time (yr) = 70

For this evaluation, the emission rates (E) and dispersion factor (DF) in Equation 6-1 were either supplied by the user or calculated by IWAIR. To solve Equation 6-2 for a resident, the summation term [sum(IRi x EDi / BWi)] was first calculated based on the values for IR, ED, and BW given in Table 4-1 of the Technical Background Document. The following table summarizes this calculation:

Receptor	Exposure Duration ED (yr)	Inhalation Rate IR (m3/d)	Body Weight BW (kg)	IR x ED / BW
Child <1	1	4.5	9.1	0.49
Child 1-5	5	7.55	15.4	2.45
Child 6-11	6	11.75	30.8	2.29
Child 12-18	7	14	57.2	1.71
Adult Resident	11	13.3	69.1	2.12
SUM {IR x ED / BW} :				9.07

The remaining values needed to calculate risk according to Equation 6-2 are CSFj, EF, and AT. The values for CSFj were taken from the IWAIR database as printed on the model output report. EF and AT for the residential scenario are defined as: 350 days per year and AT is defined as 70 years.

EF: 350 days/yr
AT: 70 years

Cancer risks were calculated for two residential exposure scenarios: vinyl chloride from a landfill; and benzene from a surface impoundment (see the accompanying IWAIR reports for each scenario). The following table summarizes my independent risk calculation and the corresponding IWAIR model results.

Case	Compound	CSF (per mg/kg-d)	Ej (g/m2-sec)	DF ([ug/m3]/[ug/m2-s])	Cairj (ug/m3)	Cancer Risk Calculated	Cancer Risk IWAIR	Ratio Calc'd : IWAIR
Landfill	Vinyl Chloride	0.3	2.20E-07	4.4	9.68E-01	3.61E-05	3.90E-06	9.25
Surface Impoundment	Benzene	0.029	1.00E-06	2.15	2.15E+00	7.74E-06	8.40E-07	9.22

APPENDIX A

Resumes for Peer Reviewers

! Alan Eschenroeder

! Douglas Fox

! Craig Mann

! Arthur Schatz

ALANOVA INCORPORATED 76 Todd Pond Road □ Lincoln, Massachusetts 01773 □ (781)259-0886

ALAN ESCHENROEDER, Ph.D.

Experience

1996- HARVARD UNIVERSITY Boston, MA

Faculty, School of Public Health. Governance committee of the Environmental Science and Risk Management Program. Teach case studies in risk and exposure assessment. Technical Advisor to the Ministry of Environment, Slovak Republic, (Harvard Institute for International Development).

1983- ALANOVA, INCORPORATED Lincoln, MA

Principal. Consulting and applied research projects analyzing exposure to chemicals transported through air, water, soil and biota. Accident hazard and health risk assessments in multidisciplinary studies of waste and industrial facilities.

1986-1990 GRADIENT CORPORATION Cambridge, MA

Member, Board of Directors. Corporate policy decisions for a consulting firm specializing in environmental risk analyses.

1984-1989 MIT LINCOLN LABORATORY Lexington, MA

Technical consultant. Analyses of and software for infrared optical signatures of flight vehicles in the high endo-atmospheric phase of reentry.

1978-1983 ARTHUR D. LITTLE, INC. Cambridge, MA

Senior management staff, Safety and Fire Technology Section. Fate of chemicals in the environment. Risk assessments for hazardous operations and substances.

1975-1978 ERT (now ENSR) Santa Barbara, CA

Managing Director. Environmental Analysis Division. Research and consulting work in environmental sciences. Air quality permitting. Photochemical air quality model development, ambient standards analyses.

1967-1975 GENERAL RESEARCH CORPORATION Santa Barbara, CA

Associate Director. Social Systems Department. Development of photochemical air quality models relating smog to emissions in the Los Angeles Basin.

1964-1966 UNIVERSITY OF CALIFORNIA, SANTA BARBARA

Adjunct faculty, College of Engineering. Lecturer in statistical thermodynamics.

1962-1967 GENERAL MOTORS CORPORATION Santa Barbara, CA
(Defense Research Laboratories)

Head, Aerophysics Section; Theoretical aerodynamics.

1959-1962 CORNELL AERONAUTICAL LAB. (Now Calspan) Buffalo, NY

Research Engineer. Aerodynamics Research Department.

1955-1957 UNITED STATES ARMY Aberdeen Proving Ground, Maryland
(Ballistic Research Laboratories)

1st Lieutenant, Research Engineer; Interior ballistics.

Education

1957-1959 CORNELL UNIVERSITY, Ph.D. 1959 Ithaca, NY

Engineering (aerodynamics and mathematics minors).

1950-1955 CORNELL UNIVERSITY, BME 1955 Ithaca, NY

Mechanical engineering. First in graduating class.

GOVERNMENT POLICY ACTIVITIES

MINISTRY TASK FORCE ON RISK MANAGEMENT (Slovak Republic, 1996-7)
Technical Advisor to environmental officials in the Slovak Republic. Support multidisciplinary planning of environmental policy leading to legislative reforms in the transitional economy. Taught short graduate level course on risk assessment for medical professionals.

NATIONAL ACADEMY OF SCIENCES, DIESEL IMPACT STUDY COMMITTEE (USEPA 1980-1982)
Member. Chairman, Environmental Impacts Subcommittee. Reported to EPA on health and environmental risks of larger market penetration of diesel cars in the United States.

NATIONAL ACADEMY OF SCIENCES, EVALUATION PANEL ON ENVIRONMENTAL MEASUREMENTS (NBS 1975-1981)
Chairman. Assumed oversight responsibility from U.S. Department of Commerce for environmental measurements and standards programs at the Bureau of Standards.

NATIONAL ACADEMY OF SCIENCES, AIR QUALITY COMMITTEE OF THE TRANSPORTATION RESEARCH BOARD (1978-1986)
Member. Coordinated research on methods of controlling transportation-related air pollution. The committee organizes and conducts the annual conference.

NATIONAL ACADEMY OF SCIENCES, SUBCOMMITTEE ON OZONE AND OTHER PHOTOCHEMICAL OXIDANTS (1975-1976)
Member. Authored two chapters (atmospheric concentrations and models for air quality; pp. 126-238) to the EPA-sponsored study which served as the basis for the oxidant criteria document revisions.

SANTA BARBARA COUNTY AIR POLLUTION CONTROL DISTRICT HEARING BOARD (1972-1975)
Vice Chair. Conducted quasi-judicial proceedings to issue abatement orders and evaluate variance applications. Originally served on committee that drafted the rules and regulations for the district.

CITY OF SANTA BARBARA, BOARD OF WATER COMMISSIONERS (1973-1978) Chair.
Formulated policy and plans for operating the city-owned public utility. Responsibilities included managing the supply of water and the treatment of wastewater.

CITY OF SANTA BARBARA, CITY COUNCIL (1969-1973)
Council member. Elected to a four- year term and served in main governing body of city of 70,000. Special contributions included participating in U.S. Congressional and Senate hearings on oil drilling in the Santa Barbara Channel.

HONORS AND MEMBERSHIPS

Listed in:

- Who's Who in the World 1990 -

- Who's Who in America 1990 -

- Who's Who in the West 1974-1989

- American Men & Women of Science 1962-

Memberships:

- Society for Risk Analysis, N.E. Chapter President 1993
- Boston Risk Analysis Group
- Air and Waste Management Association (formerly APCA)

Academic Honors:

- Sigma Xi
- Tau Beta Pi
- Sibley Prize Recipient
- Union Carbide Fellow
- Ford Fellow
- John McMullen Scholar

AIR MODELING AND RISK ANALYSIS STUDIES

PUERTO RICO - (10/97 -) Manage environmental health portions of a comparative assessment of island-wide alternatives for integrating resource recovery with municipal waste management including public health and ecological risks. Alternatives include landfilling and waste-to energy facilities in each of four prototype environments.

LOS ANGELES, CALIFORNIA - (7/97 - 10/97) Assessed human health risks to workers and to community residents posed by exposure to diesel exhaust. The sources of the diesel emissions were engines used in the Port of Los Angeles for handling and shipping bulk commodity cargo.

LOS ANGELES, CALIFORNIA - (8/96 - 2/97) Evaluated air quality impacts of alternative emissions trading schemes involving oxides of nitrogen credits for volatile organic emissions by new sources.

NATICK, MASSACHUSETTS - (8/95 - 9/95) Developed risk assessment of closed landfill considering alternative future land uses: Golf course development and gas collection system with flare. Multimedia exposure pathways were analyzed.

STATE OF OKLAHOMA - (1/95 - 11/95) Assisted Department of Environmental Quality in the evaluation of risk management plans
based on transportation surcharges for importation of hazardous wastes from out of state generators.

ATHOL, MASSACHUSETTS - (1/95 - 5/95) Assessed risks of landfill closure north of the town center in compliance with Massachusetts DEP requirements of a comprehensive site assessment. Water and air pathways were modeled, and residual risks for the baseline closure plan were mapped.

HARVARD SCHOOL OF PUBLIC HEALTH - (9/94 -) Coauthored book with other faculty members on the role of risk analysis in the greening of US industry. Analyzed policies of EPA and the Congress in reducing risks to public health by regulation and legislation in response to risk analysis results. Case study on municipal waste management. Sponsored by the Center for Risk Analysis.

NEW BEDFORD, MASSACHUSETTS - (4/94 -) Performed multimedia risk assessments for community study group, Citizens for a Clean Harbor, of remediation alternatives for the New Bedford Harbor superfund site. Served as technical advisor in selection of alternative technologies for cleanup of PCB and heavy metal contaminated sediments.

LINCOLN PARK, COLORADO - (6/92 - 5/93) Produced multimedia chemical health threats analysis for the entire community based on personal and industrial exposures. Results summarized in six companion technical reports.

CALHOUN, TENNESSEE - (8/92 - 2/93) Carried out episodic and long term air modeling of fog formation around the Bowater Paper mill to investigate causes of fog leading to multi-vehicle accidents on I-75. Detailed modeling of 12-11-90 event validated by satellite and ground-truth observations; causation and risk statistical modeling of annual visibility statistics corroborated by plant weather logs and highway patrol data sheets. Produced and directed a short video documentary analyzing the causes of the 1990 accident.

WESTERN STATES PETROLEUM ASSOCIATION (8/91 - 7/92) Performed Phase I analysis of the multiple impacts of petroleum processing facilities as determined from AB 2588 health risk assessments. Study began with a screening approach to determine clusters of sources and concluded with a case study of a particular cluster to determine the overlap of impact isopleths.

AT&T and NYNEX (sub to TRC 12/91 - 8/92) Analyzed risks and modeled consequences of accidental bentonite drilling fluid releases during drilling of telephone cable tunnels beneath rivers and estuaries in Southern Connecticut and Long Island Sound. Data were used in assessing the ecological impacts of such accidents.

SAWYER OF NAPA (7/91 - 2/92) Managed technical witness team in the first Proposition 65 lawsuit to go to trial in the State of California. Provided engineering support for environmental analysis of releases of perchloroethylene to air and water, and performed a multimedia exposure and risk assessment in the successful defense of the litigation in the Superior Court of Napa County.

NORTHEAST CONSULTANTS, INC. (10/89 - 3/91) Assessed risks of landfilling municipal solid wastes, incinerator ash and municipal wastewater treatment plant sludge at an integrated solid waste disposal facility proposed for Clinton, Massachusetts. Provided air quality and climatology sections of the Environmental Impact Report. Analyzed air pathway risks from leachate treatment.

GEORGETOWN COGENERATION L.P. (1/91 - 3/91) Analyzed the risks to residential population of spills of aqueous ammonia (used for selective catalytic NO_x reduction) from trucks and stationary facilities. Both consequences and probabilities were analyzed and presented in the study.

MUNGER TOLLES & OLSON (9/90 - 2/91) Evaluated risks of an accidental chlorine release from an industrial facility to the health of nearby residents. Time-dependent model generated maps of cloud over an eleven-hour period. Results used to produce computer video animation.

BOTANICALS INTERNATIONAL (3/90 - 12/90) Assisted in risk management of control technology for limiting releases of ethylene oxide from food sterilizers. Analysis included dispersion from stack, sewer mains and municipal treatment facilities. Risk-mapping graphics were developed and presented.

GENERAL ELECTRIC (sub to Alceon Corp. 5/90 - 7/90) Supported risk assessment of reentry guidelines for cleanup of an industrial building contaminated by dioxins in soot following a structure fire. Calculated fate of PCB and dioxins volatilizing from soot layer on room interior surfaces to the indoor air. Follow up study (10/91 - 4/92) on source culpability considered relative likelihoods of PCBs from various endogenous sources.

SOUTHERN CALIFORNIA EDISON (7/89 - 9/90) Prepared a health risk assessment in support of an RI/FS for a former manufactured gas plant site in California.

ALCEON CORPORATION (8/89 - 10/89) Identified potential hazards of discharges into water and air from a major pharmaceutical firm in Connecticut. Developed screening models of multimedia environmental fate for several major contaminants.

TOWN OF SAUGUS, MASSACHUSETTS (8/89 - 10/89) Formulated permit conditions for the Board of Health to exercise health risk management of the ash disposal system associated with added pollution control equipment for a municipal solid waste resource recovery facility.

CLEAN HARBORS OF BRAINTREE (7/89 - 9/89) Evaluated and reviewed the catastrophic risk analyses of the proposed hazardous waste incineration facility in Braintree, MA for HMM Associates.

BFI/DOUGLAS ENVIRONMENTAL ASSOCIATES (7/88 - 7/89) Screened risks of a municipal solid waste landfill in the Commonwealth of Massachusetts. Developed health risk sections of the Final Environmental Impact Report. Worked with designers to manage risks and mitigate high impacts.

TODD POND RESIDENTS ASSOCIATION (12/88 - 1/89)
Assessed the health risks of a herbicide application to control pond vegetation. Considered exposures of wildlife, wetlands and downstream water consumers. Two reports submitted in support of a wetlands permit granted by the Massachusetts Department of Environmental Protection and by the Lincoln Conservation Commission. Performed retrospective water monitoring program.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, LINCOLN LAB. (1/88- 10/88)
Compared the risk of committing an interceptor to kill a decoy with that of not committing an interceptor to a warhead in an anti ballistic missile engagement. A modified Fischer criterion was employed and the Mahalanobis Distances were estimated. Extensive analyses were necessary to compute the heating of the body under entry conditions where the flow undergoes a transition from free- molecule to continuum conditions. Ray tracing codes gave the sensor signal in terms of the emitted radiation.

SOUTHERN CALIFORNIA EDISON (7/88 - 9/88) Assessed health risks to recreational users and groundwater consumers near the Mill Creek discharge of a water treatment plant in Visalia, California at a Superfund site.

SOUTHERN CALIFORNIA EDISON (6/88 - 8/88) Prepared a preliminary appraisal of health risks associated with the disposal of spent vanadium pentoxide catalyst material used in utility boiler emission control systems.

CITIES OF BURBANK, GLENDALE AND PASADENA, CA (5/88 - 8/88)
Assessed the risks to public health and safety of anhydrous ammonia spills associated with selective catalytic reduction systems proposed for the South Coast Air Basin.

NEW YORK STATE ASSOCIATION FOR RETARDED CHILDREN (2/88 - 4/88)
Reviewed the public health impacts of a proposed medical area incinerator facility and prepared a mini risk assessment.

TOWN OF KIRKWOOD, NEW YORK (9/87 - 3/88) Evaluated the health risk assessment presented as part of the EIS for the proposed 600 ton per day Broome County Resource Recovery facility. Prepared a mini risk assessment to highlight problems and to provide the decision makers with a range of cases.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, LINCOLN LAB. (1/86 - 7/87) Analyzed the probability of error versus the probability of false alarm for targeting decisions with an anti ballistic missile system designed to discriminate targets from decoys using real time high precision radar based deceleration data. Extensive analyses were carried out for high endo atmospheric reentry conditions where the flow undergoes a transition from free- molecule to continuum conditions.

CITY OF HAVERHILL, MASSACHUSETTS (4/87 - 4/88) Assisted the City Board of Health in considering amendments to the site assignment granted previously to a 1650 ton per day resource recovery facility currently under construction. Information requests were issued resulting in the developer, Ogden Martin Systems, Inc., performing detailed health risk assessments of ash handling and stack emissions. Worked with legal/technical team to formulate language for modifying the design of the system.

SOUTHERN CALIFORNIA EDISON COMPANY (2/84 - 4/88) Performed a public health endangerment assessment of the remediation activities, past and future, of a former pole treatment yard site in Visalia, California, which is a superfund site.

CITY OF ONTARIO, CALIFORNIA (7/87 - 12/87) Evaluated the health risk assessment of the Milliken resource recovery facility on behalf of the Planning Department of the City. Delivered a report to the City pointing out areas of improvement needed in the health risk assessment. The report also addressed concerns which might be mitigated through a conditional use permit required for operation. The facility, proposed by the Ogden Martin Systems, Inc., was designed to process 1600 tons of municipal waste per day.

SIGNAL ENVIRONMENTAL SYSTEMS, INC. (3/86 - 10/87) Managed research for, prepared documentation of, and testified on behalf of health risk analysis in support of the application for certification for the 60 megawatt San Diego Energy Recovery (SANDER) facility proposed for San Diego, California.

PACIFIC WASTE MANAGEMENT CORPORATION (3/85 - 4/86) Managed preparation, documentation, and testimony for the health risk analysis in support of the application for certification for the 80 megawatt Irwindale Resource Recovery Facility proposed for Los Angeles County, California.

SOUTHERN CALIFORNIA EDISON COMPANY (5/84 - 9/86) Performed health risk assessment of exposure of human populations to the combustion products of transformer fires on the system. The analysis began with combustion dynamics calculations, proceeded through air modeling and inhalation exposure pathways.

SOUTHERN CALIFORNIA EDISON COMPANY (5/86 - 11/86) Performed a health risk assessment of land use alternatives and remediation alternatives for a former manufactured gas plant site.

KOCH CARBON, INC. (10/83 - 3/85) Assessed risks of nuisance dust episodes for petroleum coke storage areas in support of a proposed regulatory amendment before the South Coast Air Quality Management District Board of Directors.

SOUTHERN CALIFORNIA EDISON COMPANY (9/83 - 2/84) Performed exposure modeling and prepared health risk assessment of PCB spills from electrical transmission equipment for system-wide operations.

U.S. ENVIRONMENTAL PROTECTION AGENCY (8/78 - 12/82) Assessed health risks of multipathway exposures to the priority pollutants named in the settlement agreement with the NRDC.

SELECTED PUBLICATIONS IN ENVIRONMENTAL SCIENCES

A Health Risk Assessment of Human Cancer due to Diesel Exhaust emitted at the Kaiser International Corporation report to Broiles & Timms, Los Angeles, California. September 1997.

Coping with Municipal Waste (With A. Cullen) in The Greening of Industry based on a Harvard Center for Risk Analysis research project 1994-1996. Published by Harvard University Press 1997.

Baseline Qualitative Risk Assessment of the Landfill at Natick, Massachusetts (with K. von Stackelberg), Tata & Howard, Inc. for the Town of Natick, September 1995.

Baseline Qualitative Risk Assessment of the Landfill at Athol, Massachusetts (with K. von Stackelberg), Tata & Howard, Inc. for the Town of Athol, May 1995.

Computer Modeling of Smog in Southern California (with K. von Stackelberg) A videographic documentary. August 1994.

Videographic Mapping as a Tool for Risk Communication (with K. von Stackelberg) Society for Risk Analysis seminar, May 1994.

Effects of an Accidental Release of Chlorine in the Los Angeles Basin (with K. von Stackelberg) A videographic documentary. May 1994.

Gas/Particle Partitioning Effects on Dioxin Exposures from Incinerators (with A. Cullen and K. von Stackelberg) a paper presented at the U.S. Environmental Protection Agency Ninth Annual Regional Risk Assessment Conference, April 25-27, 1994

Industrial Fog: A Factor in the Accident at Calhoun, Tennessee?
(with K. von Stackelberg) A videographic documentary. April 1994.

Chemical Health Threats to Citizens of Lincoln Park, Colorado (with K. von Stackelberg and A. Taylor) Alanova, Inc, series of six reports prepared for Holmes Roberts and Owen, Denver, Colorado, April - May 1993.

Multisource Health Risk Impacts of Petroleum Processing Facilities (with K. von Stackelberg, C. Blanchard and P. Roth) Alanova, Inc. a report prepared for the Western States Petroleum Association, July 1992
Health Risk Assessments: Air Transport and Exposure Pathways (with K. von Stackelberg), Proceedings of the Fourth International Conference on Municipal Solid Waste Combustor Ash Management & Utilization, Arlington, VA, November 12-13, 1991.

A Composite Risk Index Approach for the Assessment of Multimedia Risks from MSW Landfill Gas Contaminants (with K. von Stackelberg) Air and Waste Management Association 84th Annual Meeting and Exhibition, Vancouver, BC June 16-21, 1991.

Aqueous Ammonia Spill Risks Associated with a SCR System on a Cogeneration Facility (with K. von Stackelberg) Alanova, Inc. report to Georgetown Cogeneration, L.P., March 1991.

Health Risks of Alternative Methods of Municipal Solid Waste Disposal: A Massachusetts Comparison (with S. Wolff, A. Taylor and D. Burmaster) Society for Risk Analysis, 1990 Annual Meeting, New Orleans, LA October 7-10, 1990.

Health Risks of Alternative Methods of Municipal Solid Waste Disposal: A California Comparison (with S. Wolff, A. Taylor and D. Burmaster) Air and Waste Management Association Paper 90-182.3 presented at the 83rd Annual Meeting and Exhibition, Pittsburgh, PA June 24-29, 1990.

Mass Balance of Perchlorethylene from Spills at a Dry Cleaning Facility (with D. Burmaster and K. Thompson) Alanova, Inc. report to Hollyway Cleaning April 1990.

The Health Risks of Fugitive Ash Emissions from the Haverhill Resource Recovery Facility Ash Monofill (with P. Guldberg) Air and Waste Management Association Paper 89-6.9 presented at the 82nd Annual Meeting, Anaheim, CA June 25-30, 1989.

Fugitive Dust Emitted from the Hold of a Ship While Offloading Bulk Cement Cargo, Alanova, Inc. Report prepared for Wilmington Liquid Bulk Terminals, Inc. March 3, 1989.

A Calculation of Safe Levels of PCDD/F in the Discharges from the SCE Water Treatment Plant in Visalia, California, Alanova, Inc. Report prepared for Southern California Edison Company, January,
1989.

A Determination of Human Exposure to Chloroform in the Discharge of the SCE Treatment Plant at the Former Pole Yard Site at Visalia, California, Alanova, Inc. Report prepared for Southern California Edison Company, January, 1989. (with S. Wolff)

An Identification of Disposal Hazards of Spent Catalyst From Air Pollution Control Systems Using SCR, Alanova, Inc. Report prepared for Southern California Edison Company, July 1, 1988. (with C. Petito, L. Tatelbaum and B. Beck)

Update of an Analysis of the Risks of Injuries and Deaths From Future SCR Ammonia Spills in Southern California, Alanova, Inc. Report prepared for Southern California Edison Company, July 1, 1988.

"A Monte Carlo Analysis of Health Risks from PCB-Contaminated Mineral Oil Transformer Fires", Risk Analysis Vol. 8, No. 2, June 1988, pp. 291-297. (with E.J. Faeder)

An Impact Assessment of the Fugitive Dust Levels in Azusa, California Residential Lands Attributable to Rock Processing at Azusa Rock, Inc., Alanova, Inc. Report prepared for Richards, Watson & Gershon on behalf of Azusa Rock, Inc., June 30, 1988.

Analyses of the Public Health and Safety Threats of SCR Ammonia Spills in the Cities of Burbank, Glendale and Pasadena, California, Alanova, Inc. Report prepared for Richards, Watson & Gershon for Burbank, Glendale and Pasadena, June 20, 1988.

A Quantitative Assessment of the Fugitive Dust Impacts of Rock Processing and Transport of Residential Lands in Duarte, California, Alanova Inc. Report prepared for Richards, Watson & Gershon on behalf on Azusa Rock, Inc., June 2, 1988.

An Analysis of the Human Casualty Risks From SCR Ammonia Transport and Handling in Southern California, Alanova, Inc. Report, May 7, 1988. (with D. Burmaster)

A Review of the Public Health Aspects of the Draft Environmental Impact Statement for the Proposed Incinerator Facility at Letchworth Village, NY (preliminary review draft), Alanova, Inc. Report prepared for Robinson, Silverman, Pearce, Arohnsohn & Berman, April 25, 1988. (with S. Wolff)

A Health and Environmental Endangerment Assessment (EA) of the Former Pole Yard Site at Visalia, California, Alanova, Inc. Report submitted to the California Department of Health Services, Northern California Section, Toxic Substances Control Division by Southern California Edison Company, April 15, 1988. (with C. Petito, S. Wolff, D. Burmaster and C. Buril)

A Preliminary Health Evaluation of Mill Creek Water and Sediment in Visalia, California, Alanova, Inc. Report submitted to California Regional Water Quality Control Board, Central Valley Region by Southern California Edison Company, February 5, 1988. (with S. Wolff and C. Petito)

Criteria for and Evaluation of the Health Risk Assessment of Stack Emissions from the Proposed Resource Recovery Facility at Haverhill, MA, Alanova, Inc. Report prepared for the City of Haverhill Board of Health, January 20, 1988.

Douglas G. Fox, Ph.D., QEP
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Douglas G. Fox Qualifications for this project

I have been developing and reviewing air quality modeling for over 30 years.

* My earliest publication on the subject is a paper in the Journal of Geophysical Research in 1968, based on my Ph. D. dissertation research at Princeton University in the Civil Engineering Department. The paper developed a new model for plume rise under stable atmospheric conditions.

* From 1972 -- 1974, I worked for the EPA in Research Triangle Park, as Chief of the Model Development Branch of the air quality research group. In this capacity I supervised the initial development of a number of new air pollution dispersion models including the first photochemical airshed models, the first models developed to predict wind flow and dispersion for complex topography, innovative urban models, and the first regulatory models.

* From 1976 -- 1982, I served as one of the four founding members of the initial peer review activity for regulatory models initiated by the EPA. This activity led to the development of the EPA Air Quality Dispersion Modeling Guideline, specifically mandated in the 1977 Amendments to the Clean Air Act, and continuing as the primary reference for regulatory air quality modeling.

* As a member of the American Meteorological Society/EPA Dispersion modeling review committee, I led efforts to develop statistical methods for model evaluation and validation. These methodologies are adopted and used as standard procedures in the EPA Modeling Guideline.

* My research activities through the 1980's involved the initial development of modeling tools incorporated in the CalMet and CalPuff modeling system, currently being promulgated as the preferred model for PSD permitting under the Clean Air Act.

* I have published well over 100 research papers and reports on the development, application and validation of air dispersion models.

* Currently, I am engaged in the development of regulatory models in support of EPA's developing policies on fine particulate and regional haze, specifically dealing with smoke generation from agricultural and forestry burning.

Resume

Douglas G. Fox

Over 35 years of professional experience in environmental management. For the past three years, I have been in private practice as an environmental consultant, serving a customer base that includes, private companies, a professional society, the US Environmental Protection Agency, the US Agency for International Development, and Universities. My consulting includes developing tools to enhance community-based environmental activities, air pollution transport modeling, ecological risk assessment and its management, climate change, cleaner production and environmental management. I also serve on the adjunct faculty of the University of Colorado at Denver, Environmental Sciences program, and the senior scientific staff at the Cooperative Institute for Research on the Atmosphere at CSU. I am a visiting faculty for the pan European post graduate course on Environmental Conservation and Remediation of Mountain Environments hosted by the University of Turin in Italy. Active in climate change, I was a lead author for the Intergovernmental Panel on Climate Change (IPCC) Working Group II, Effects, Adaptation and Mitigation. I currently provide editorial oversite review for the monthly Environmental Compliance News published by Elsevier and serve on the Editorial Board for Atmospheric Environment. and the Air Pollution Consultant

I was the President of the Air & Waste Management Association in 1993-1994. Currently, I lead A&WMA's global expansion having been responsible for establishing member units in Mexico, Saudi Arabia, Taiwan, Hong Kong, Korea, Philippines, Brazil and the European Union. I am currently working on developing groups in India, Malaysia, Singapore, Sri Lanka, India and China.

I have over 25 years experience as a federal program manger and research leader, working for the USDA, Forest Service, Department of Commerce and the Environmental Protection Agency. At the Forest Service I directed and conducted research on air resources management (both technology and policy,) complex terrain meteorological and dispersion modeling smoke management, and effects of air pollution on forest ecosystems.

My education is in civil engineering, graduating from the Cooper Union in New York City and obtaining a Ph. D. from Princeton University in the same field.

I am certified as a Qualified Environmental Professional (QEP) by the Institute of Professional Environmental Practice, a credential supported by the Water Environment Federation, The American Academy of Environmental Engineers, the Solid Waste Association of North America, the Air & Waste Management Association, the National Association of Environmental Professionals, and the State & Territorial Air Pollution Program Administrators & Association of Local Air Pollution Control Officials (STAPA/LAPCO). The QEP is an examination and experience based credential.

I recently completed ISO14001 Lead Auditor Training and am qualified as an instructor for ISO14001 lead auditor training by the ANSI-RAB.,

A brief résumé of my capabilities and experience follows.

Environmental Management

Extensive management experience conceptualizing, organizing, funding and leading projects dealing with a broad spectrum of environmental issues, including climate change, acid rain, air pollution impacts on natural areas, air pollution source permitting, visibility protection, air and environmental impacts modeling, forest and park land protection. Activities included policy & funding development and issue management, field studies, experimentation in laboratory and field condeitions, analysis and interpretation of data, and analytical and computer simulation modeling. Convening Lead Author of IPCC Working Group II: Climate Change, 1995 Chapter 6 "Effects of Climate Change on Mountain Environments," and coauthor, "Summary for Policy Makers."

Accomplished Scientist

Over 30 years experience developing tools and technologies dealing with environmental pollution and its effects on natural ecosystems, specifically climate change, air pollution, GIS decision support tools, community-based risk evaluation, simulation modeling, effects of climate on mountain ecosystems and atmosphere/forest interactions. Wide variety of environmental problems solved. Personal research accomplishments in air pollution recognized through use and application for scientific and regulatory purposes, in the United States, Australia, Asia and Europe. Authored over 130 papers and reports in various fields of research and development. Expert in climate change effects on ecosystems, U.S. Clean Air Act dealing with prevention of significant degradation (PSD) issues, Class I area modeling and assessments.

International Leader

International recognition as an innovative and creative leader in environmental management. President (1993-94) of the 13,000 member Air & Waste Management Association, and currently leading the Association international outreach. International experience in eastern and western Europe, Mexico, Australia, and Asia. Currently associated with environmental activities and projects in China, Hong Kong, India, Italy, Malaysia, Korea, Poland, Sri Lanka, and Taiwan.

Education

The Cooper Union, New York City; B. C. E., 1963
Princeton University, M. S. E., 1965
Princeton University, M. A., 1965
Princeton University, Ph. D., 1968

Experience & Capabilities:

Independent consulting practice assisting clients:

~ expand international activities,
~ formulate strategies dealing with climate change and sustainable development,
~ improve community-based environmental decision-making,

~ comply with air pollution permitting under the U.S. Clean Air Act, especially with regard to air quality modeling.

~ develop Smoke Management Programs, including state of the science tools to predict smoke behavior.

Senior scientist, Cooperative Institute for Research in the Atmosphere,
Colorado State University. air quality and climate change research. PM2.5 modeling development, especially associated with identifying natural background levels and visibility impairment.

Professor of Environmental Sciences, University of Colorado at Denver. teaching & student research on climate change and environmental management, including ISO 14001 and alternative voluntary environmental management programs..

Founding Director, The TERRA Laboratory. a multi disciplinary, multi agency research center assessing regional effects of climate change for the US Global Change Research Program, funded by USDA, DOI, EPA, Colorado State University, CIESIN and IBM.

Forest Service Global Change Program Manager, Interior west U.S. A major research program studying effects of climate and air pollution on forests.

Research Leader, USDA- Forest Service. Developed procedures and tools for the federal land managers to deal with air pollution and especially to comply with the US Clean Air Act responsibilities, including visibility and other Air Quality Related Values of Class I and Wilderness areas. led western acid rain research, led fire and smoke management research.

Branch Chief, US Environmental Protection Agency. Meteorological and air pollution modeling research leader.

Senior Scientist, National Center for Atmospheric Research. GCM, climate and smaller scale interactions model development.

Additional activities:

~ Published over 130 journal articles, books and other professional papers,

~ Consulting Editor, Environmental Compliance News,

~ Editorial Board, Atmospheric Environment & J. of Air & Waste Management,

~ Chaired and participated in numerous international and national panels.

Professional Level: **P4**
Total Years of Experience: 16

Education
M.Ed., University of North Carolina at Chapel Hill

Employment History

1991 – Present	Environmental Quality Management, Inc., Director of Training and Program Development.
1989 – 1991	International Technology, Inc., Environmental Scientist.
1982 – 1989	PEI Associates, Inc., Environmental Scientist.

Exposure Assessment Experience

Mr. Mann was responsible for the development of the air pathway exposure assessment for calculating the U. S. EPA Soil Screening Levels (SSLs) for the Superfund program. This entailed theoretical modeling of vapor-phase and particulate matter emissions and dispersion from contaminated surface and subsurface soils. Final guidance published by the EPA includes a tiered approach to estimating SSLs. The first tier includes calculation of generic SSLs based on national default model parameters. Mr. Mann developed these default parameters based on model sensitivity analysis and parameter distribution data. Subsequent tiers for estimating SSLs involves the use of more rigorous simulation models. Mr. Mann has subsequently refined the vapor-phase emission models used for calculating SSLs to include calculation of vapor-phase concentrations in buildings due to vapor intrusion from subsurface soils. Mr. Mann produced two simulation models for vapor emissions from soils that presently reside on the U. S. EPA NCEA and OSWER websites. The first model estimates vapor emissions from soils based on diffusion while the second estimates vapor concentrations in buildings. These models are considered to provide second tier estimates of exposure point concentrations and subsequent incremental risks.

Mr. Mann has also reviewed and validated emission models for the EPA to assess air impacts during the remediation of Superfund sites. Model analysis includes screening and refined models for estimating short- and long-term emissions from soil vapor extraction, excavation and materials handling, and bioremediation. The results of this effort are to be included in future revisions to the Risk Assessment Guidance for Superfund: Part C, Risk Evaluation of Remedial Alternatives. Mr. Mann is presently involved in producing for the EPA a protocol and methodology for both calculating risk and reverse-calculating risk-based SSLs for construction of a commercial/industrial facility at a hazardous waste site. These methods are to be used in a future EPA publication concerning potential risks from other than residential land uses at Superfund sites.

Selected Documents

Environmental Quality Management, Inc. 1999. A Methodology for Estimating Inhalation Incremental Risks and Soil Screening Levels for Construction at a Hazardous Waste Site. U.S. EPA Contract No. 68D7003. Prepared for the Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC.

Environmental Quality Management, Inc. 1998. Modeling Lateral Migration of Volatile Contaminants in Subsurface Soils. U.S. EPA Contract No. 68D7003. Prepared for the Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC.

Environmental Quality Management, Inc. 1997. User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings and Computer Spreadsheets. U.S. EPA Contract No. 68D30035. Prepared for the Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC.

Environmental Quality Management, Inc. 1996. A Review of Mathematical Models for Estimating Volatile and Particulate Matter Emissions from Soil Excavation/Materials Handling and Bioremediation. EPA Contract No. 68D30035. Prepared for the Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, DC.

Environmental Quality Management, Inc. 1995. Limited Validation of the Jury Infinite Source and Jury Reduced Solution Finite Source Models for Emissions of Soil-Incorporated Volatile Organic Compounds. EPA Contract No. 68D30035. Prepared for the Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, DC.

Environmental Quality Management, Inc. 1994. A Comparison of Soil Volatilization Models in Support of Superfund Soil Screening Level Development. EPA Contract No. 68D30035. Prepared for the Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC.

Environmental Quality Management, Inc. 1994a. A Modeling Analysis of the Effects of Particulate Matter Emissions on the Inhalation Soil Screening Levels. EPA Contract No. 68D30035. Prepared for the Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC.

Environmental Quality Management, Inc. 1993. Evaluation of the Dispersion Equations in the Risk Assessment Guidance for Superfund (RAGS): Volume I – Human Health Evaluation Manual (Part B, Development of Preliminary Remediation Goals). EPA Contract No. 68-02-D120. Prepared for the Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC.

U. S. Environmental Protection Agency (EPA). 1996. Emission Model for Soil Organic Fate and Transport (EMSOFT) User's Guide and Computer Program. National Center for Environmental Assessment, Washington, DC. NCEA-W-0073.

U. S. Environmental Protection Agency (EPA). 1996a. Air/Superfund National Technical Guidance Study Series: Guideline for Predictive Baseline Emissions Estimation for Superfund Sites. Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA-451/R-96-001.

Biographical Data

ARTHUR D. SCHATZ

Senior Risk Assessor

Experience Summary

Arthur Schatz has over 18 years of experience in managing and conducting human health risk assessments and air quality projects. He is an expert in human health risk assessments for CERCLA and RCRA hazardous waste sites, combustion sources and other toxic air pollutant sources. He is knowledgeable in state and EPA risk assessment guidance, state and federal air toxics regulations, air emission and dispersion modeling techniques, and environmental fate and transport modeling.

Experience Record

1994-Date Parsons Engineering Science. **Senior Risk Assessor.** Manages and conducts multimedia risk assessment projects for hazardous waste sites and industrial facilities and manages air quality studies. Performs multimedia fate and transport analyses to estimate chemical exposures. Directs risk-driven air monitoring and modeling studies, including occupational and indoor air investigations.

Risk Assessor for CERCLA Remedial Investigation for the Seneca Army Depot in New York State. Assessed human exposures to and health risks from organic chemicals and metals related to historic munitions disposal practices at the facility. Assessments have considered various future uses for areas of the site including conservation land, industrial/commercial development, and a state prison. Developed approach to assess worker indoor air exposures to waste materials in buildings from former operations. Estimated potential exposures and risks from inhalation of dust and vapors during construction activities, inhalation of vapors released from water during showering, and ingestion and dermal contact with soil and water. Evaluated children's risks from exposure to lead in soil for a potential future daycare center at the site, using USEPA's biokinetic uptake model for lead. Both current and future risks were assessed, based on projected land uses for the site. Risk assessments have been reviewed and accepted by the Army, EPA Region 2 and NYSDEC.

Exposure Modeler for Office of Special Assistant for Gulf War Illnesses (OSAGWI). Developed modeling approaches to estimate exposures of US troops to pesticides during the Gulf War. Estimated inhalation exposures to specific pesticides under range of indoor and outdoor uses by applying atmospheric dispersion models, indoor air model (EPA's MCCEM) and other approaches. Modeling results will be used in comprehensive qualitative risk assessment of pesticide use during the war.

Risk Assessor for several CERCLA Remedial Investigation/Feasibility Studies. Surveyed federal and state regulations and identified applicable or relevant and appropriate requirements (ARARs) for remedial alternatives under consideration. Analyzed data from ambient air monitoring network at a CERCLA site to assess health risks of mercury emissions from an on-site incinerator. Modeled vapor and particulate emissions from site remediation activities.

Project Manager for risk driven indoor/outdoor air toxics monitoring study at a commercial building in Massachusetts. Designed and oversaw study to assess potential influx of organic chemical vapors into the occupied building from soil and groundwater at the site. Measurements achieved extremely low detection limits to satisfy requirements of the Massachusetts Contingency Plan and site-specific requirements dictated by the Massachusetts DEP. Showed that vapor intrusion was not a pathway of exposure at this building based on air measurements and fate/transport analysis.

Risk Assessment Task Manager for RCRA Remedial Facility Investigation at the Sikorsky Aircraft facility in Stratford, Connecticut. Developed work plans for human health and environmental risk assessments based on historical site data and new data collected in 1995-1996.

1988-1994 ENSR Consulting and Engineering, Acton, Massachusetts. **Senior Scientist/Project Manager** for risk assessments and for air quality projects.

Health Risk Analyst for more than 10 CERCLA/RCRA sites including chemical plants, bulk storage terminals, and petroleum-contaminated sites. Estimated potential human exposures and risks with up-to-date fate and transport models, to realistically estimate releases of over 30 volatile and semivolatile organic compounds, including BTEX and PAHs, from contaminated soils and ground water. Calculated health risks from various indoor and outdoor exposure pathways. Evaluated both on-and off-site impacts under baseline conditions and for various remedial scenarios. Prepared risk assessment reports which were submitted to state agencies and USEPA regional offices.

Emissions and Exposure Modeler for RCRA Remedial Facility Investigation at the Reilly Industries facility in Indianapolis, IN. Calculated exposures to chemicals in soil and ground water for workers and offsite receptors using various techniques and models. Modeled air emissions of VOCs contained in process wastewater discharges throughout the wastewater collection and treatment system, and calculated potential onsite and offsite exposures. Reported results to EPA Region 5 as part of the site RCRA RFI risk assessment report.

Task Manager for model development project for USEPA's Exposure Assessment Group. Developed screening model that calculates air emissions from contaminated soils and tracks residual soil concentrations, for application in CERCLA/RCRA site risk assessments. The model, called Emission Model for Soil-Organic Fate and Transport (EMSOFT), is a user-friendly, menu-driven program that considers multiple fate mechanisms, i.e., volatilization, sorption, leaching and biodegradation. Validated model performance against data from laboratory and field studies. EPA approved the model and users manual, and has posted both to its website.

1985-1988 Gradient Corporation, Cambridge, Massachusetts. **Senior Associate, Project Manager** for human health risk assessment of planned remedial activities for the Hyde Park Landfill CERCLA site, Niagara Falls, New York. Modeled dispersion of dust and vapors from the site and advised EPA Region II on the adequacy of the air monitoring provisions plan to protect public health. Technical report documenting the evaluation of the proposed program was accepted by U.S. District Court.

Project Manager for air quality and hazardous waste management projects. Conducted air modeling studies, risk assessments and developed air monitoring plans for government and private clients. Project work included risk assessments for resource recovery facilities and remediation and litigation support activities for CERCLA sites.

1983-1985 Camp Dresser and McKee, Inc., Boston, Massachusetts. **Environmental Scientist.** Conducted site-specific exposure and risk assessments for hazardous waste site remedial investigations and feasibility studies. Evaluated fate and transport phenomena for groundwater contamination projects. Planned and conducted air monitoring programs for hazardous waste sites.

Education

M.S. in Environmental Health Sciences, June 1982, Harvard School of Public Health, Boston, Massachusetts
B.S. in Chemistry, June 1976, State University of New York (SUNY), Oneonta, New York

Professional Affiliations/Registrations

Air And Waste Management Association
Society for Risk Analysis - New England Chapter

Presentations And Publications

Schatz, A.D., Takacs, K.C., and Dasinger, A.M., "Development and Validation of a Model to Estimate Organic Air Emissions from Contaminated Soil," presented at the 9th Annual Contaminated Soils Conference, Amherst, MA, October 1994.

Heinold, D.W. and Schatz, A.D., "Air Toxics Modeling for Public Health Protection During Superfund Site Remediation," *Proceedings of the 86th Annual Meeting of the Air and Waste Management Association*, Denver, CO, June 1993.

Schatz, A.D., Psaris, P.J., and Roll, R.R., "Emissions Measurements and Air Quality Impact Analysis for a Sludge Heat Dryer, *Proceedings of the 85th Annual Meeting of the Air and Waste Management Association*, Kansas City, MO, June 1992.

Schatz, A.D., "Air Quality Requirements for CERCLA Site Cleanups," presented at the National Meeting of the American Institute of Chemical Engineers, Pittsburgh, PA, August 1991.

Schatz, A.D. and Smith D.G., "Detection of Organic Vapors Permeating Buildings From Groundwater," *Proceedings of the 83rd Annual Meeting, Air & Waste Management Association*, Pittsburgh, PA, June 1990.

Schatz, A.D., "Risk Assessment of Air Stripping to Remediate a Contaminated Drinking Water Supply", presented at the Annual Northeast State/EPA Waste Management Meeting, October, 1986.

APPENDIX B

Charge to Peer Reviewers:
Industrial Waste Air Model

CHARGE TO REVIEWERS

Peer Review of:

EPA's INDUSTRIAL WASTE AIR MODEL

INTRODUCTION AND BACKGROUND:

There are three programs established underneath the Resource Conservation and Recovery Act (RCRA): solid waste, hazardous waste, and underground storage tanks. The RCRA solid waste program (subtitle D waste) focuses on state and local governments as the primary planning, regulating, and implementing entities for the management of nonhazardous solid waste, such as household garbage and nonhazardous solid waste. EPA provides these state and local agencies with information and guidance to help states and the regulated community make better decisions in dealing with waste issues and to promote the use of safer units for solid waste disposal. While the EPA has developed federal criteria for some subtitle D waste (i.e., municipal solid waste landfills) there are not federal regulations covering the management of industrial wastes in industrial landfills, surface impoundments, waste piles, and land application units. The regulation of these units is the sole responsibility of states and local governments.

To assist States, local governments, and industry in developing appropriate management actions for these units, the EPA entered into a joint effort with representatives from state environmental agencies, industry, and environmental interest groups to develop a voluntary guidance for the management of industrial solid waste. The Guidance recommends developing management practices that are tailored to the risk posed by a specific unit. To enhance the quality of the analysis that will determine the appropriate management practices for a specific unit, the Guidance includes two models, one that calculates risks from the air pathway and one that recommends a liner type by evaluating the ground water pathway.

The purpose of the air model, the Industrial Waste Air Model (IWAIR), is to determine the potential risks to nearby receptors or workers that may occur as a result of volatile emissions from the waste management unit. The State, local authorities, and other interested parties would then use this information to determine if emission controls should be used for the waste management unit.

The following are four goals that IWAIR is to achieve:

1. the model should provide reasonable estimates of risk from a specific unit for the direct inhalation pathway;
2. the model should be simple enough to use that it can be run by users with different levels of technical knowledge and experience in environmental fields including members of the general public;
3. the model should be capable of running with very little data on the facility (enables the public to use it);
4. finally, the model should be flexible enough that users can enter in alternative emissions data, dispersion data, and/or toxicity benchmarks.

IWAIR contains three modeling components. The first is an emissions model that estimates the emission of specific constituents from the unit into the atmosphere. The second component of the model estimates atmospheric dispersion of constituents and ambient air concentrations at a specific receptor point. The third, the risk component of the model, combines constituent concentrations at the specified receptor point with receptor exposure factors and toxicity benchmarks to estimate risk.

Emissions: IWAIR incorporates the emissions model CHEMDAT8. Once a user enters data to characterize the unit and waste, CHEMDAT8 calculates the emission rate. CHEMDAT8 was developed by the EPA and has undergone extensive peer review. IWAIR allows a user to enter site-specific data for these parameters or to rely on default data to calculate emissions.

Dispersion: The dispersion model used in IWAIR is EPA's model Industrial Source Complex Short Term Version 3 (ISCST3). ISCST3 is a complex model and running it to develop a new dispersion factor for each site and waste management unit requires extensive meteorological data and technical expertise. In order to create an easily accessible and user-friendly modeling tool to evaluate the dispersion of air emissions, ISCST3 was previously run to generate a database of dispersion factors. The dispersion factors are included in IWAIR and have been calculated for many separate scenarios designed to cover a broad range of unit characteristics. There is a dispersion factor for each combination of:

- 29 meteorological stations, chosen to represent the nine general climate regions of the continental U.S.,
- 4 unit types,
- 14 surface area sizes for landfills, land application units and surface impoundments, and seven surface area sizes and two heights for waste piles,
- 6 receptor distances from the unit, placed in...
- 16 directions in relation to the edge of the unit.

The default dispersion factors were derived by modeling each of these scenarios, then choosing as the default the maximum dispersion factor for each waste management unit/surface area/meteorological station/receptor distance combination. Based on the size and location of a unit specified by the user, IWAIR selects an appropriate dispersion factor from these modeled scenarios. If the user specifies a unit surface area that falls between two of the sizes previously modeled, a linear interpolation method incorporated into IWAIR will estimate dispersion in relation to the two closest unit sizes.

The advantage of this approach to dispersion modeling is that IWAIR provides you with a quick, easy-to-use method to calculate dispersion. Relying directly on ISCST3 requires significant technical expertise, access to very complex and resource intensive model, and substantial amounts of data. On the other hand, a limitation of the model is the fact that it does not reflect the particular conditions of a specific location.

Risk Model: This component of IWAIR combines the constituent-specific emission rate with the dispersion factor to calculate a concentration in the air at a specified receptor location. IWAIR calculates adult worker or resident exposures based on inhalation, body weight, exposure duration and frequency, and ambient concentrations of constituents at a specific receptor location. Default values for these parameters are based on EPA's Exposure Factors Handbook. IWAIR relies on standard health benchmarks (cancer slope factors for carcinogens and reference concentrations for noncarcinogens) to calculate risk or acceptable waste constituent concentrations.

IWAIR can be used two ways. Forward calculation uses known constituent concentrations in a waste to calculate risk to receptors at specified locations. Backward calculation starts with a target risk level at a specified receptor location. The model then calculates backwards to concentration levels in waste that can be protectively managed in a unit without exceeding the target risk level.

MATERIALS OFFERED FOR REVIEW:

To be reviewed according to the charge:

EPA's Industrial Waste Air Model (IWAIR)
Technical Background Document for IWAIR
User's Guide for IWAIR

CHARGE TO THE REVIEWERS:

The intention of this peer review is to determine if IWAIR is appropriate and meets the four goals that were listed above. Peer review is meant to ensure that science is used credibly and appropriately in the work performed. The primary function of the peer reviewer should be to judge whether the choice, use, and interpretation of data and the derivation and models used in the assessments are appropriate and scientifically sound thereby achieving the purpose that EPA intends the model to be used for.

As a reviewer of IWAIR, you should use your best technical knowledge and professional judgment to comment on the technical accuracy, completeness and scientific soundness of the model. It is also imperative that the reviewer remember the goals of the model when developing comments. In addition, it is extremely important to not only comment on inadequacies but to suggest a specific solution or alternative and make recommendations for improvement that will still maintain the spirit of the goals listed above. The peer review should only consider the scientific credibility of the model including applicability, uncertainty, and utility (including potential mis-use) of results, but should not advise the Agency on specific regulatory decisions or policy stemming in part from consideration of the model output.

In reviewing the software and accompanying documentation, the reviewers are requested to focus on:

1) the overall model performance;

2) specific model features;

3) the parameters used;

4) and, the quality of the software and documentation.

Specifically:

<u>I. Overall Model Performance</u>

1. Given the goals of the model, is IWAIR an appropriate tool to use? Does the model provide a reasonably accurate representation of the risk from a unit? Does the model perform well over a range of input values and scenarios? How can the model be improved?

2. A user of IWAIR is given one of two results, the risk from the unit or the concentration of a chemical that can be present in the unit to remain under a certain risk threshold. The intention of IWAIR is to provide information to the user on whether or not emission controls should be placed on a waste management unit. Are the types of results that IWAIR provides appropriate for this analysis? If not, what results would be more appropriate for determining whether or not a waste management unit should have emission controls?

3. The Guidance recommends that facilities control particulate emissions from waste management units. As a result, IWAIR assumes that particulate emissions are negligible and are not included as part of the modeling. In addition, IWAIR only evaluates the direct inhalation risks. Is this adequate for the chemicals considered (when answering this question, please keep in mind that there is another model for the groundwater pathway)?

<u>II. Specific Model Features</u>

4. Does the flexibility to change emissions rates, dispersion factors, and toxicity benchmarks make a more robust tool or diminish the accuracy of the results? Explain why. Are there other parameters in the model that the user should have the ability to override?

5. Is the modeling approach that relies on matching limited site-specific information to previously calculated dispersion factors a reasonable method to estimate dispersion of constituents from a unit? If not, how should dispersion be calculated for these waste management units if the model is to remain quick, easy to use, and not require an extensive amount of data?

6. Are the number of representative meteorological stations sufficient for assigning previously calculated dispersion factors? If not, how many should be added and where?

7. Are the assumptions made for the dispersion modeling appropriate (i.e., flat terrain, rural vs. urban, etc.)?

8. Have the boundaries surrounding a meteorological station that assign a region to a station been assigned appropriately and with a reasonable methodology? Is there a better method for assigning facilities to a meteorological station?

9. Is Chemdat8 an appropriate emissions model to use in IWAIR. Do you think that the emissions estimates calculated by Chemdat8 over predict, under predict, or provide a reasonable prediction of the emission rate from a unit?

10. Are there other tools or modeling approaches that would better serve the purpose of the location-adjusted analysis? If so, what are they?

11. ISCST3 is sensitive to the size of the area of the source. To obtain a dispersion factor for a specific waste management units surface area, an interpolation routine was used. Is this an appropriate method for estimating the dispersion for a specific surface area? Is there a better method?

III. Parameters Used for WMU's:

12. Comment on the assumptions and parameter ranges used for in the model that are shown on the attached tables (Tables 1-4). Are the assumptions appropriate for the type of analysis? Are the parameter ranges reasonable and reflective of the range of unit characteristics and conditions encountered in real situations?

13. Comment on the default values shown on the attached tables (Tables 1-4) that are assigned to some of the key parameters. Do these defaults seem reasonable, would other default values be more appropriate? If so, what are they or where can the data be found to develop better defaults

14. Comment on the assumptions that were used in the dispersion modeling to develop the dispersion factors. Are these assumptions appropriate for developing dispersion factors around industrial facilities? If not, how should they be changed?

15. The emissions calculation performed by Chemdat8 uses either Henry's law or Raoult's law depending on whether the waste is aqueous or oily. For oily (organic wastes), the model uses Raoult's law and the liquid-to-air partition coefficient becomes proportional to the contaminant's vapor pressure. For aqueous wastes, the model uses Henry's law and the liquid-to-air partition coefficient becomes proportional to the contaminants Henry's law coefficient. The rule of thumb used in assigning which way the waste will be modeled using IWAIR is dependent on the fraction of organics in the waste. Once the user has specified

the constituents in the waste, IWAIR will estimate the fraction of organics. If the waste contains more than 10% organic material then the emissions are estimated using Raoult's law. Is this rule of thumb scientifically accurate? Is there a better method of choosing which way the emissions should be modeled?

16. There are several checks in IWAIR designed to ensure that the parameters entered by a user are realistic. For example, IWAIR checks the tilling depth of a land application unit in relation to the depth of application that is calculated from inputs by the user. Please comment on all the checks in IWAIR. Do these checks capture unrealistic entries? If not, recommend an alternative.

17. IWAIR can model the risk for 95 constituents (volatiles, semi-volatiles, and mercury.) These are the chemicals that were selected by OSW to model in study, the Air Characteristic Study, that evaluated the potential direct inhalation risks from certain waste management units. The chemicals were selected for the Air Characteristics Study based on their potential to generate a risk via the inhalation pathway. Are there other chemicals that are commonly used in industry that should be added to the list of constituents considered in IWAIR?

IV. Risk Assessment

18. IWAIR will calculate the additive risk from the carcinogens. Considering additive risk for non-carcinogens is more uncertain due to target organ or multiple organs effects. Should a means for adding together the non-carcinogens be added to IWAIR? If so, please suggest a method.

19. Are the risks appropriately characterized for the cancer and non-cancer risks?

20. Review and comment on the Newton-Raphson Method used in the back calculation approach in IWAIR. This information is contained in Section 6 of the Technical Background Document.

V. The Quality of the Software and Documentation

21. Comment on the ease-of-use and logic of IWAIR.

22. Comment on the nature of the instructions within the program. Are they clear and easy to understand?

23. Comment on the layout of the user-interface screens. Are all easy to use and read?

24. Comment on the presentation of results. Are they consistent and easy to understand?

25. Comment on the ease of installation and file manipulation (saving and retrieval?)

26. Comment on the logic and clarity of the documentation. Were any important points, assumptions missing or inadequately explained?

27. Comment on the structure of the user's guide. Is it easy to follow? Are there any inconsistencies with the software?

28. Comment on the readability of the user's guide. Can it be used by an individual without a lot of air modeling experience including members of the general public?

29. Comment on the structure of the Technical Background Document. Is the modeling approach and logic used for development clear?

30. Is there sufficient explanation concerning the structure and assumptions in the model? What else should be described?

31. Comment on the readability of the Technical Background Document. Is it written at a level appropriate for someone with some environmental training and modeling experience?

Table 1. Ranges/Default Values for Input Parameters for Landfills

Input Parameter	Units	Default Value	Min	Max	Comments
Unit Design and Operating Parameters					
Operating Life of Landfill	years	None	>0	none	
Total Area of Landfill - All Cells	m^2	None	>0	none	
Average Depth of Landfill Cell	m	None	>0	none	
Total Number of Cells in Landfill	unitless	None	>0	none	
Average Annual Quantity of Waste Disposed	Mg/yr	None	>0	none	
Waste Characterization Information					
Dry Bulk Density of Waste in Landfill	g/cm^3	1.4	>0	none	
Average Molecular Weight of Oily Waste	g/gmol	147	>0	none	
Total Porosity of Waste	volume fraction	0.50	>=0	<=1	This is a fraction, so is limited to 0-1 by definition.
Air-filled Porosity of Waste	volume fraction	0.25	>=0	<=total porosity	Max is a physical limitation.

Table 2. Ranges/Default Values for Input Parameters for Land Application Units (LAUs)

Input Parameter	Units	Default Value	Min	Max	Comments
Unit Design and Operating Parameters					
Operating Life of LAU	years	None	>0	none	
Tilling Depth of LAU	m	None	>0	none	
Surface Area of LAU	m^2	None	>0	none	
Average Annual Quantity of Waste Applied	Mg/yr	None	>0	none	
Number of Applications per Year	yr^{-1}	None	>0	none	
Waste Characterization Information					
Dry Bulk Density of Waste/Soil Mixture	g/cm^3	1.3	>0	none	
Average Molecular Weight of Oily Waste	g/gmol	282	>0	none	
Total Porosity of Waste/Soil Mixture	volume fraction	0.61	>=0	<=1	This is a fraction, so is limited to 0-1 by definition.
Air-filled Porosity of Waste/Soil	volume fraction	0.5	>=0	<=total porosity	Max is a physical limitation.

Table 3. Ranges/Default Values for Input Parameters for Wastepiles

Input Parameter	Units	Default Value	Min	Max	Comments
Unit Design and Operating Parameters					
Height of Wastepile	m	None	>0	none	
Surface Area of Wastepile	m^2	None	>0	none	
Average Annual Quantity of Waste Added to waste pile	Mg/yr	None	>0	none	
Dry Bulk Density of Waste	g/cm^3	1.4	>0	none	
Waste Characterization Information					
Average Molecular Weight of Waste	g/gmol	147	>0	none	
Total Porosity of Waste	volume fraction	0.5	>=0	<=1	This is a fraction, so is limited to 0-1 by definition.
Air-filled Porosity of Waste	volume fraction	0.25	>=0	<=total porosity	Max is a physical limitation.

Table 4. Ranges/Default Values for Input Parameters for Surface Impoundments

Input Parameter	Units	Default Value	Min	Max	Comments
Unit Design Data					
Depth of Liquid in SI	m	None	>0	none	
Surface Area of SI	m^2	None	>0	none	
Average Annual Flow Rate	m^3/yr	None	>0	none	
Aeration Data					
Fraction of Surface Area Agitated	unitless	0.25	>0	<=1	This is a fraction, so is limited to 0-1 by definition. Since it is only requested if user chooses aeration, it must be greater than 0 (0 implies no aeration).
Submerged Air Flow Rate	m^3/s	0	>0	none	
Mechanical Aeration Information					
Oxygen Transfer Rate	lb O_2/h-hp	3	>0	none	This has a very narrow range (2.9 to 3.0) and is rather obscure (i.e., user could easily not have any clue about the appropriate range). Propose including a warning if a value outside this range is entered, and the user could either cancel (and change it) or choose explicitly to proceed anyway.
Number of Aerators	unitless	1	>0	none	
Total Power Input to All Aerators	hp	75	>0	none	
Power Efficiency of Aerators	fraction	0.83	>0	<=1	Has a very narrow range (0.80 to 0.85) and is rather obscure (i.e., user could easily not have any clue about the appropriate range). Propose including a warning if a value outside this range is entered, and the user could either cancel (and change it) or choose explicitly to proceed anyway.
Aerator Impeller Diameter	cm	61	>0	none	
Aerator Impeller Rotational Speed	radians/s	130	>0	none	
Waste Characteristic Data					
Average Molecular Weight	g/gmol	282	>0	none	
Active Biomass Conc. (as MLVSS) in the SI	g/L	0.05	>=0	<=TSS	This is a subset of TSS, so cannot be greater than TSS.
Total Suspended Solids (TSS) in SI Influent	g/L	0.2	>=0	<=1,000	Cannot exceed density of waste (presumed by CHEMDAT8 to be 1 kg/L = 1,000 g/L).
Total Organics (TOC or COD) in SI Influent	mg/L	sum of chem conc entered (exclude mercury)	>=sum of chem conc entered (exclude mercury)	<=1,000,000	Must be at least as much as implied by chemical concentrations entered for waste. Cannot exceed density of waste (presumed by CHEMDAT8 to be 1 kg/L or 1,000,000 mg/L).
Degradation Rate of Total Organics	mg/g biomass-h	19	>=0	none	

APPENDIX C

Detailed Comments on IWAIR from Peer Reviewers

- Alan Eschenroeder, Ph.D.
- Douglas Fox
- Craig Mann
- Arthur Schatz

Review of

Industrial Waste Air Model Documents and Software

By

Alan Eschenroeder, Ph.D.

Harvard University

Introduction

The development of IWAIR is a useful embodiment of two off-the-shelf EPA models, which have enjoyed widespread application in the past. The software implementation of the scheme works smoothly and has very few glitches. The software scheme is relatively transparent, and its documentation is accordingly clear in its linear presentation of model operation. For a significant range of applications the model should be useful for the purposes guiding its design. This review addresses a series of areas where improvements are possible in the documentation or the model design. There are places where good judgment has been exercised, and there are other places where some improvements are indicated. Before presenting the review, it may be helpful to outline the organization of the review in these introductory remarks.

This review moves from the general to the particular. It begins with suggestions for improvements in both the writing style and the technical content. The next section responds to selected questions from the charge to reviewers. Finally, this review lists specific points where clarification, revisions or expansions might improve the document.

Improvements in Style of Presentation

The IWAIR model software synthesizes the algorithms and specific calculations from other pre-existing models. This places a special responsibilities on the author of the technical background documentation; namely,

- to provide an independent stand-alone description of each component model that is embedded in IWAIR,
- to present clearly and completely the assumptions in and limitations of each predecessor model and
- to convince the reader that the capabilities of the component models are appropriate for the IWAIR application.

The document attempts to fulfill these goals, but the result is rather uneven. Some of the introductory material is clear, but other discussions are either unnecessarily abbreviated or absent altogether.

All this having been said, it is the belief of this reviewer that the technical report should undergo some changes in its style of presentation in order to achieve its stated objectives. First and foremost it is essential in the rewrite process to retain a professional publications editor who will play the role of devil's advocate. This is the single most constructive comment than can be offered on behalf of achieving the objectives and repairing the problems enumerated elsewhere in this review. Such detailed assistance is beyond the scope of this review.

Improvements in Technical Content

An executive summary added to each of the two documents (User's Guide and Technical Background Document (TBD)) will aid in relating the technical elements of the presentation and will provide a clear overview of the content from beginning to end. This section should clearly state in one to five pages the objectives of the document; why the work was done and what is hoped to be its application. Some of the background in the present "Introduction" more properly belongs in the executive summary. Furthermore, it should summarize the technical approaches without going into detailed descriptions. The general conclusions or applicability of the work should appear at the end of the executive summary.

The introduction of the technical work reported will benefit from expanding on one of the recognized steps in health risk assessment; namely, hazard identification. This would clarify the reasoning governing the choices of substances and pathways. In addition, this will provide the opportunity to present a simplistic screening analysis that combines contamination levels with threats to human health. Without this information, one might guess that the list was assembled from what could be found easily in the literature. Descriptions of approaches are generally thorough; however, lapses occasionally leave the reader wondering just what was done or what is really going on. Specific citations below back up all of these general observations.

The appendices form a nice compendium of information, but they deserve more discussion in the main text link them with the technical goals of the documentation. For example, no particular value judgments seem to be forthcoming after the extensive presentation of sensitivity studies of ISC3 in Appendix D of the TBD. Moreover, CHEMDAT8, the other cornerstone model, seems to have escaped the same degree of scrutiny afforded ISC3. Specifically, the report fails to present sensitivity studies of CHEMDAT8 (e.g., to data uncertainties) despite the fact that its reliability is equally crucial to the success of IWAIR. Either the dispersion model sensitivity studies should be omitted or the CHEMDAT8 sensitivity studies added.

Responses to Selected Charge Questions

I. Overall model performance

1. model operation

a) Yes. b) Yes, if its application is restricted to the volatile compounds on the list. c) The model does not always perform well over a range of input parameters. Some of the limit values are lower than soil saturation values, thereby failing to address cases within the realm of possibility. The model can be improved by informing the user how default values are used. This is never mentioned. Also, it would be helpful to provide help screens for entry level users that explain how equations listed in the TBD produce numbers on the various model screens.

2. results

The results given are appropriate. Going any farther with interpretation would push the user into forced choices in risk management. Some cautionary labeling might be added to the results screen to remind the user of the model's limitations.

3. Particulate emissions

Though clearly called out in the peer review charge, the EPA's decision to not address particulate emissions is not raised in the TBD. Including particulate emissions in IWAIR would greatly complicate the model because the semi-volatile compounds (a few like BaP and PCDDs probably should not have been included in the IWAIR list) generate indirect exposures by their entry into the soil and surface water compartments. This pathway could be added as a logical branch to IWAIR or could be treated as a stand-alone model. The latter is probably preferable because the processes of emission, deposition and subsequent exposure involve specific and different calculation approaches.

The issue reduces itself to whether or not EPA wishes to include semi-volatile organic compounds in IWAIR. If they are omitted, a fair amount of complication is avoided, and all organic compounds are assumed to be volatile. If they are included in a volatile emitted phase, IWAIR should include indirect pathways involving at least air-to-plant transfers. These transfers enter the human food chain through produce, and the agricultural food chain through forage, silage and grain. The dairy or beef animals, which consume these feeds, further bioconcentrate in the animal tissue products entering the human food chain. (See comment 17. For further measures needed to include semi-volatile compounds)

II. Specific Model Features

4. Flexibility

The degree of flexibility with respect to options for user intervention is just about right. Too many more would be confusing, and fewer would unduly limit the model's versatility. I'm still wondering what values have been assigned as default dispersion factors are. This procedure is not documented in the TBD. No notice of them ever appears in the model screens.

5. Dispersion factors

The generic approach to zoning off the contiguous 48 states seems to be appropriate as far as it goes. How about Hawaii, Alaska or Puerto Rico? Why are they missing?

6. Met stations

Pardon my provincialism, but some thought might be given to more coastal representation. For example there are a lot of New England coastal areas represented by Hartford, which has a distinctly inland valley climatology.

7. ISC assumptions

From a practical sense, one just about has to go with flat terrain to avoid the requirement of a digitized terrain database. These sources are surface based or low level; therefore terrain features will not be as prominent as in cases of elevated point sources. Nevertheless, there could be a screening of the zip codes or lat-long to put up warning signs for certain geographic locations in which the flat terrain assumption may not work. For example, a simple algorithm could compare the elevation of the receptor with the elevation of the source, using USGS digitized terrain data.

8. Met boundaries

See answer to 6.

9. Appropriateness of CHEMDAT8

For volatile chemicals, CHEMDAT8 may not cover certain pathways like droplet entrainment, accidental leaks and spills and fugitive emissions from waste handling equipment. For the pathways covered, CHEMDAT8 is probably satisfactory in that its assumptions net out to slight overestimates. For semi-volatile chemicals, the particulate issue could be an important source not covered by CHEMDAT8. (see answer to 3.)

10. Available alternatives

Subject to the limitations, which should be more clearly stated in the TBD, the choices of models and data serve the purpose of the location-adjusted analysis.

11. Area interpolation within ISC3 output tables

Judging from the ISC3 unit concentration output tables in the technical support document, I believe that interpolation among the different areas calculated is within the expected accuracy of the model.

16. Checks

The checks built into the software seem adequate.

17. Chemicals chosen

As mentioned elsewhere in this review, there seem to be several semi-volatile compounds represented on the list. This seems to raise some problems. If they are retained, the questions of particulates and of indirect pathways arise. Also, if you keep BaP and 2,3,7,8 TCDD, there are a whole host of relatives in their chemical families that do not appear on the IWAIR list, but for which fate data exist. In cases of both the PAHs and the PCDD/Fs it is likely that the omitted compounds will be at higher concentrations in typical wastes than the compounds on the list with the possible exception of naphthalene. In a model which professes to treat semi-volatile contaminants, certainly the members of the PCB family must be included. If the treatment of semi-volatile compounds is eliminated, some important sources of risk may be left out of the calculation. The agency must make a judgment call: include all of the semi-volatile compounds (including PCBs) along with additional significant pathways or take them out altogether without apology, but with the proviso that the model is intended for use with volatile compounds only. Mercury should be retained, but guidance on speciation must be provided because of differing toxicity (e.g., mercury, methyl mercury and divalent mercury). Surprisingly, IWAIR gives cancer risk output for mercury, but no non-cancer risk! This is counter to Table 5-1 which correctly shows that non-cancer, rather than cancer effects are the issue with mercury exposure. Also, with mercury, we run into the multimedia problems because of possibly some being on particles and because of possible indirect pathways. In this sense, the dilemma with mercury is similar to that with semi-volatile organic compounds.

If dioxins and furans are retained, carrying them in the liquid compartment at the solubility limit and assuming vapor after volatilization into the air pathway is valid for the conditions of interest to the model user. (All bets are off, however, if these compounds already are adsorbed to fugitive dust particles). Several years ago we examined the problem of dioxin vapor to particle ratios in plumes. We found that once the plume reached ambient conditions of temperature and particle loading, the times characterizing the condensation of vapor on particle surfaces were long compared with residence times in urban areas. Thus, I would support the modelers' assumption of once emitted as vapor, the dioxins remaining in vapor phase until they reach receptors located a few hundred meters away. Below is an order of magnitude calculations supporting the exclusion of condensation of dioxins and furans on pre-existing particulate matter in the air.

Three assumptions define a bounding calculation for depletion of vapor by condensation on particle surfaces:

(1) Every dioxin molecule that reaches the particle surface sticks to that surface

(2) Any migration of dioxins to particles does not reduce the vapor phase concentration

(3) The instantaneous surface concentration of dioxin molecules is always zero

The last two assumptions violate the conservation of mass in favor of health conservatism, but we are trying to calculate a bound, not an exposure.

The mass transfer to a surface is defined by a mass transfer coefficient *k* defined by

$$k = \frac{Flux}{(c_1 - c_o)}$$

where c_1 is the average mass concentration of dioxin vapors in the air parcel and c_o is the concentration of dioxins immediately adjacent to the particle which we set equal to zero to maximize the flux. The mass transfer coefficient for particles that move at air velocity is given by $k=D/r$ (see for example Seinfeld, J.H., 1986: *Atmospheric Chemistry and Physics of Air Pollution,* Wiley-Interscience, New York, p.267) where D is the diffusion coefficient of dioxins in air (taken to be 5E-02 cm^2/s) and r is the particle radius (taken to be 5µm to represent particles presenting large surface areas). The particulate concentration χ is assigned the value of $100 \mu g/m^3$; another value chosen to maximize available surface area. If the density of the particle mass is ρ_p, then the number of particles per unit volume of air is $3\chi/4\rho_p\pi r^3$ and the surface area of particles per unit volume is $3\chi/\rho_p r$. Let us assume that the wind is blowing at 3 m/s so that the flight time of the average air parcel from the disposal facility to the receptor that is 300m downwind is 100 s. Applying the definition of the mass transfer coefficient given above, we get a fractional change in vapor concentration over this time interval to be given by

$$\frac{\Delta c_1}{c_1} = \frac{3D\chi t}{\rho_p r^2}$$

Substituting the values designated in the narrative above we find that $\Delta c_1/c_1$ is only 0.003, which is a negligible fraction attaching to particles even under the extreme limiting assumptions adopted. Therefore, the assumption of all vapor phase dioxins out to the receptor is a reasonable approximation of reality if the dioxin enters the air in the vapor phase.

III. Risk Assessment

18. Additivity of non-cancer risks

No, the non-cancer risks should not be additive if they represent different end-points; however, it is useful to display in the output the sum of the health hazard quotients (sometimes called the health hazard index) for screening purposes. The idea of screening is if the totality of health hazard quotients is far less than one, there is no need to break it down further. Both the component and total values should be displayed on the screen with a footnote about screening. Subtotals for like endpoints are also appropriate; for example, if chemicals A, B and C all cause upper airway irritation, it is logical to add their health hazard quotients.

19. Risk characterization

Under the restriction to volatile compounds acting only through the inhalation pathway, the risks are appropriately characterized. There are, however, some questions that need answering along the way in the risk calculation. See specific comments for these questions.

20. Newton-Raphson Method

The Newton-Raphson Method is applied to the determination of roots of coupled simultaneous nonlinear algebraic equations. It uses the first term in the Taylor expansion of the equation to estimate the next trial for determining the root. One of its chief applications is the solution of chemical equilibrium compositions of multi-component systems. In the application presented in the IWAIR technical background document, it is really difficult to see why the program needs to use this method. First of all, the equations are linear, and second of all, the needed factors are all pre-calculated by the software. At first, I thought that maybe the unit concentration calculation introduced some nonlinearity, but that factor is calculated in a straightforward manner from the definition of the scenario. Likewise, the CHEMDAT8 output in the emissions screen is linearly dependent on the waste concentration so that, again, straightforward calculation is possible without iteration. For example consider the coupling between Eq. 6-4 and 6-9. Specifying acceptable risk, we can use 6-4 directly to obtain Cair. Then, moving along to 6-9, we can solve out for Cw from knowledge of Cair, Eunit and DF. The first of these three came from 6-4, and the latter two factors are generated on screens prior to the inverse calculation. Maybe I am missing something, but it would appear as if Newton-Raphson is not necessary. It causes the only noticeable pause in the execution of the program, so its elimination would be welcomed if this were possible.

IV. Quality of Software and Documentation

Generally, the user documentation is adequate. When I tried to install the software, it refused to load on the D:\ drive, my CD ROM drive. I discovered that the CD ROM had an embedded virtual E:\-drive on it. Once I prompted it to load on E:\ everything worked fine. This is a bit esoteric for the entry level user, don't you agree? Perhaps this could be fixed. Also, a help function with a library of backup screens would be essential for the beginner. The setting of receptor distances seemed awkward with all of the little pull down menus. Maybe it would be better to have a big array where you could just click on the values you wanted. As mentioned above, the whole notion of default receptor parameters is a bit mysterious. Are the default directions with distances preset? See further comments below.

Specific Comments

Title: Will there be an industrial surface and ground water model? -- or a dust model? These pathways are not commented on in the reports.

Sec. 1.1 needs to say up front that the model is only intended for inhalation of volatile organic substances and mention what is being done about the rest of the universe of waste contaminants. The word "organic" is an adjective, not a noun.

CHEMDAT8 seems to be limited to steady state emissions by volatilization, and it appears to neglect biogas generation. In view of the numerous biodegradation rates given in the chemical tables, it seems strange that none of this biodegradation is allowed to result in gaseous products. In aerobic degradation carbon dioxide and water vapor seems to be the end of the line and in anaerobic processes, carbon dioxide and methane are produced. Where does all of the advection of these products come into the emission model? This looks like a violation of mass conservation. Clearly IWAIR admits biodegradation as a decay mechanism, then why not allow an option for major waste components to biodegrade? In so doing they decompose into simple molecules made up of carbon (methane and carbon dioxide), hydrogen (methane and water vapor), and oxygen (water vapor). The option would allow the user to enter gas generation potential and rate. In turn IWAR would apply these data to calculate the biogas flow from the management facility. A partitioning calculation in the waste mass provides the toxic contaminant concentrations in the biogas flowing out to the atmosphere, and, hence, the advection-driven emissions of toxic organic compounds.

At the bottom of p 2-11 it seems to say that the volume of the land treatment remains a constant in spite of new waste being added. As stated this seems to fly in the face of common sense. The issue of mass conservation is skirted by saying that what was there previously is eliminated from the problem by burying it deeper than before. Does this remove it from the problem as a contributor to emissions once it is beyond a certain depth? Based on the information provided in the TBD, it is not possible to determine exactly how IWAIR treats waste volume. EPA has models for buried waste that could be utilized for different burial times and different depths. Since they are linear, the solutions could be superposed. Obviously this is either inadequately explained or just plain wrong. As written it is not possible to judge.

Eq 2-9 omits all the terms from n=1 to n=n-2, and the parenthetical factor multiplying the (n-1)st term further decreases the mass in place because the application depth is always less than the tilling depth. I believe the code does it correctly and that this is an inaccurate representation of what goes on -- especially in view of what Eq. 2-10 seems to say. These comments probably indicate a lack of understanding on my part; therefore, a careful rewrite of this section will assure the correct interpretation.

Eq 2-11 implies that the fraction emitted is independent of the fraction biodegraded. Try to find a functional connection between these two. It probably exists, and it would be helpful in the conservation of mass.

Section 3 and following passages alternate between "dispersion factors", "UACs" and "unit concentrations." This ambiguity in terminology is unnecessarily confusing. I prefer unit concentrations, but please pick one term and stay with it throughout the document and the program screens. How was the worst case chosen? What are "defaults"? How do the sixteen directions figure in? (they do not appear on the screens) What is the receptor geometry in terms of "squares"? This section needs the work of a good technical editor because it is really difficult to try to figure out what is going on as it is written. Refining the resolution of the receptor grid almost always turns up higher peak values. This seems to be almost treated as a discovery in this section.

Page 3-3 Maybe it is not worth bothering to mention the undefined unreferenced "Dalenius-Hodges" procedure, if in the end, the spacing turns out to be arbitrary anyhow.

Page 3-5 states "Large scale regional average conditions were used to select the actual stations". The reader deserves a few more sentences on what it was that (EQM and Pechan, 1993) did to help in this selection. Also, would it be possible to supply a definition of "conflation"?

Beginning on page 3-11 the charts show a reassuring low degree of sensitivity of UAC to geographical location. Maybe I don't have to worry so much about coastal climatology as I did in a comment above in response to the charge questions.

Page 4-1 Unnecessary confusion is caused by Table 4-1 because it seems to summarize some of the information provided in the rest of the tables in section 4. Then each of the subsequent tables has slightly different age stratification. This probably comes right out of the Exposure Factors Handbook, but the curious reader might like to know why these different categorizations exist among the tables. It might improve readability to replace the age stratified exposure parameters in the tables with a simple adult and child breakdown. As it stands, the age categories for the calculation do not coincide so that the interpretation of aggregate calculations becomes both confusing and inconsistent. In addition, the authors should provide an explanation of why central tendency exposure values were selected (as noted on page 4-1), even if they simple state that this is in keeping with standard EPA risk assessment practices.

Section 5 second sentence reads:"Unit Risk Factors (URFs) and CSFs are used in the model for carcinogenic constituent regardless of the availability of an RfC." This is a *non sequiter* because RfCs could not replace either URFs or CSFs since they (RfCs) only apply to non-cancer end points.

Appendix C is a nice write up of the toxicology profiles.

Appendix D traces through the details of several sensitivity runs of the ISC3 dispersion model. There is no indication of what the author's error tolerance was, or how it influenced the choices of assumptions in IWAIR. Moreover, it is not explained why no sensitivity studies of CHEMDAT8 were undertaken.

Peer Review of EPA's Industrial Waste Air Model (IWAIR)

Douglas G. Fox

20 August 1999

I have approached the review of the EPA Industrial Waste Air Model (IWAIR) by responding to the specific questions presented to us in our charge. My answers are listed below.

1. a) Given the goals of the model, is IWAIR an appropriate tool to use?
   Yes, it is appropriate.
   b) Does the model provide a reasonably accurate representation of the risk from a unit?
   In my opinion, it does provide a risk estimate that is of sufficient accuracy to provide a reasonable estimate based on the direct inhalation pathway associated with a specific site,
   c) Does the model perform well over a range of input values and scenarios?
   I ran the model over a wide range of input values and scenarios, and found it to perform well, dispersion values were appropriate based on my experiences and screens and results without any noticeable flaws. The only error I encountered was a "Runtime Error '13' Type Mismatch" a few times when I had added and removed chemicals on Screen 2. This happened about three or four times, but it was not a regular or consistent bug, I found no particular pattern to it.
   d) How can the model be improved?
   One area of improvement would be in the treatment of meteorological data. While the selection of 29 meteorological stations as being representative appears to have statistical validity based on earlier work, it nevertheless represents a weakness in the approach. Meteorological data are not regionally defined and use of regional representations invariably introduces error into a calculation. In my opinion, for the purposes of this modeling and based on the nature of the calculation, looking over a long time period at accumulated risk, it is acceptable to use the 29 representations. However, I think accuracy would improve if local meteorological data could be used (as allowed in the model) where ever possible. In answer to Question 8b, I suggest how I think the use of on-site meteorology might be better accommodated.

2. Are the types of results that IWAIR provides appropriate for determining whether a unit should have emissions controls?
   Yes, they are very appropriate. I can not think of a better way to think about emission controls.

3. The guidance recommends that facilities control particulate emissions from waste management units. As a result, IWAIR assumes that particulate emissions are not included as part of the modeling. In addition, IWAIR only evaluates the direct inhalation risks. Is this adequate for the chemicals considered?
   Especially with the impending new regulations on PM2.5 (regulations were issued last year but subsequently enjoined by the DC Circuit court) I question if this is adequate. I

am not sure if it is possible for particulate material of aerodynamic diameter less than 2.5 micrometers to either be directly emitted or to form through photochemical and or aqueous phase atmospheric chemical reactions from emissions from these waste facilities. If it is possible, which seems likely to me, should not this risk to health also be evaluated as part of this assessment? I would think it should and profiles for these particulate emissions should be developed. I should point out that this is potentially a very major task. Thus, it could be the subject for further releases of updates to this model, rather than holding up release of this version. This seems especially appropriate, as the issue of the standard is still to be resolved legally.

4. a) Does the flexibility to change emissions rates, dispersion factors, and toxicity benchmarks make a more robust tool or diminish the accuracy of the results & why?
   The flexibility to change these factors, adds to the model capability and improves its final accuracy, assuming that competent and knowledgeable professionals apply the model.
   b) Are there other parameters in the model that the user should have the ability to override?
   First, I have already stated that on-site meteorology would improve model accuracy. Second, on Screen 5B, when the user identifies dispersion factors, the user should also enter the receptor(s) distance(s) appropriate for the entered factors. At present, the model specifies only the specific pre-selected values (25, 50, 75, 150 and 1,000 meters) that cannot be changed. The user who will be exercising an air quality dispersion model to generate these coefficients, should be allowed to enter appropriate receptor distances. When the user enters "override" dispersion factors they will be calculated for specific receptors, the user should be able to input these receptor distances. This can represent a small check on the user who is entering dispersion factors to ensure that the user understands these represent a specific place in space, i.e. a receptor distance.

   Third, I think this is a minor point, but the shape of the waste facilities and their orientation toward the wind appears to exert a significant influence on dispersion. Table D2 (b) shows that UAC values could be as much as 50% different depending upon waste configuration and its orientation at specific sites. Model developers, therefore, selected a square source to minimize errors because "..no data on source shape or orientation is [are] available.." . While, I doubt if it would be a major factor, a parameter to represent a correction to the UAC for waste shape and orientation with respect to on-site meteorology might be added. Perhaps, something like, multiplying the UAC by 1.5 if the longer dimension of the waste facility is greater than 2 times the shorter dimension and it is within + 30 degrees of the prevailing wind direction.

5. (a) Is the modeling approach that relies on matching limited site-specific information to previously calculated dispersion factors a reasonable method to estimate dispersion of constituents from a unit? If not, how should dispersion be calculated for these waste management units if the model is to remain quick, easy to use, and not require an extensive amount of data?

   Yes, it is. However, I have two suggestions that might improve model accuracy while still maintaining needed simplicity.

I have some concern about the use of 29 meteorological data sets to represent their regions. We know that meteorology does not lend itself toward this sort of regional averaging. While, the spatial association that is done in the model may be useful as an initial approach, I suggest that an alternative method that could select a more representative meteorology be developed. My thought is that some sort of local meteorological data should be required. On-site is best, but a local meteorological station that has annual surface level wind distributions (wind rose) will suffice. The user could then input this local wind rose data and the model could search the 29 sets of meteorological data to find the one most like the input wind rose.

Second, somewhat related to the local representative meteorological data issue above, the model documentation is clear in identifying that it is only applicable in areas of "simple" terrain. "Simple" terrain is more an exception than the rule and it might be helpful to add a conservative (over-predicting) default for terrain that is significant relative to, say the height of inversions or stable layers in the area. (This again might be determined from local or on-site meteorology) For this situation, a conservative "box" model, whose dimensions are defined by an estimate of stable layer height (perhaps 300 meters could be a default value) multiplied by an area. The dimensions of the area could be estimated by how far emissions might travel in a days time, multiplying the lowest end of the wind speed distribution (say average of the lowest 10% of a year of hourly wind speeds) times 24 hours. This volume (300 m x WS m/s x 24x360 s) then would be divided into the total emission of chemical in question in 24 hours to estimate a concentration. This concentration would be applied at whichever receptors lie within its boundaries. The resulting UAC could be applied 10% of the time in a typical year. This sort of a backstop to support the unlikely potential for terrain driven stagnant conditions increasing concentrations. I have not had sufficient time to evaluate the impact such a calculation might make on actual concentrations. It is possible that it will not substantially change outcomes. Even if concentrations are an order of magnitude higher, for 10% of the year (I estimate an order of magnitude, 10% of the time, would be an upper limit on how much concentration could increase) the result will only double the UAC. From the model calculations that I ran, this is not likely to have a significant effect in most cases.

Finally, a third point, by fixing receptor distances, maximum ground level concentrations are not necessarily calculated. This is not likely to be significant except in the case of the elevated source waste pile emissions where the fixed receptor distance could miss the maximum ground-level concentration.

6. Is the number of representative meteorological stations sufficient for assigning previously calculated dispersion factors? If not, how many should be added and where?

   I think that, with the addition of the Box model mentioned above, the number is sufficient.

7. Are the assumptions made for the dispersion modeling appropriate (i.e. flat terrain, rural vs. urban, etc.)?

Yes, they are for the rural vs. urban dispersion coefficients. I have suggested a procedure that could deal with the terrain issue. Alternatively, a sensitivity analysis of terrain could be done to show that this sort of a calculation would not make any significant difference.

8. (a) Have the boundaries surrounding a meteorological station that assign a region to a station been assigned appropriately and with a reasonable methodology?

   I have above suggested an alternative approach. Using Bailey's ecoregions to help define specific boundaries for the 29 regions is creative and valuable. However, in many regions the diversity of meteorological observations can be just as large within one of these regions as across regions. I know that, for example, in the western regions, say the one represented by Denver, meteorological conditions are dramatically different based on the elevation and surrounding topography of the site. I believe the diversity of conditions in this region is as great as the diversity represented in all 29 of the selected stations. I have not had time to look at the EQM and Pechan, 1993 reference that is presented as a justification for representing the 200 Station's data available on EPA/SCRAM, but, even the SCRAM data set is quite limited in its representation of actual meteorological conditions.

   (b) Is there a better method for assigning facilities to a met. Station?

   I think the method selected may be appropriate as a rough screening approach but this should be quantified somehow. One approach, provide information about how many of the 200 meteorological sites mentioned above are reasonably represented by their selected regional site. The model can be improved with addition of a provision that would allow a simple comparison of local meteorology with the representative station to determine if it is acceptably similar or not and an algorithm that could search the 29 meteorological data sets to determine the one that is most closely representative could be added. This is addressed earlier in answer to question #1.

9. Is CHEMDATA8 an appropriate emissions model to use in IWAIR? Do you think that the emissions estimates calculated by Chemdat8 over predict, under predict, or provide a reasonable prediction of the emission rate from a unit?

   I have no experience with CHEMDATA8 but it certainly seems to be the most appropriate source for emissions data. It has been widely reviewed and is well known in the community.

10. Are there other tools or modeling approach that would better serve the purpose of the location-adjusted analysis? If so, what are they?

   I think the most appropriate tools have been used. The only suggestion would be to do something like suggested above in answer to questions # 5 & 8.

11. ISCST3 is sensitive to the size of the area of the source. To obtain a dispersion factor for a specific waste management units surface area, an interpolation routine was used. Is this an appropriate method for estimating the dispersion for a specific surface area? Is there a better method?

Size of the unit is a critical parameter; however, the interpolation method being used seems to be appropriate. I think any more complex interpolation would not yield significantly different results.

12. Comment on the assumptions and parameter ranges used for in the model. Are the assumptions appropriate for the type of analysis? Are the parameter ranges reasonable and reflective of the range of unit characteristics and conditions encountered in real situations?

They appear to be appropriate given the objectives of the IWAIR model.

13. Comment on the default values (Tables 1-4) that are assigned to some of the key parameters. Do these defaults seem reasonable, would other default values be more appropriate? If so, what are they or where can the data be found to develop better defaults?

Default values seem appropriate and reasonable. The only addition, I would suggest, is adding default limits on a number of the physical parameters associated with the size of the facility, e.g. Table 1 Total Area of Landfill set to size of the largest existing facility, Average annual quantity of waste, same idea, etc.

14. (a) Comment on the assumptions that were used in the dispersion modeling to develop the dispersion factors. Are these assumptions appropriate for developing dispersion factors around industrial facilities?

As mentioned above, the assumptions about dispersion factors are appropriate with the possible exceptions noted

(b) If not, how should they be changed?

Suggestions involving use of on-site or local meteorology, an approximation for very stable conditions and a facility shape factor have been suggested above for consideration.

15. The emissions calculation performed by Chemdat8 either uses Henry's Law or Raoult's law depending on whether the waste is aqueous or oily. For oily (organic wastes), the model uses Raoult's law and the liquid-to-air partition coefficient becomes proportional to the contaminant's vapor pressure. For aqueous wastes, the model uses Henry's law and the liquid-to-air partition coefficient becomes proportional to the contaminants Henry's law coefficient. The rule of thumb used in assigning which way the waste will be modeled using IWAIR is dependent on the fraction of organics in the waste. Once the user has specified the constituents in the waste, IWAIR will estimate the fraction of organics. If the waste contains more than 10% organic material then the emissions are estimated using Raoult's law. Is this rule of thumb scientifically accurate? Is there a better method of choosing which way the emissions should be modeled?

This is beyond my area of competence, although it seems reasonable, I cannot answer the question.

16. There are several checks in IWAIR designed to ensure that the parameters entered by a user are realistic. For example, IWAIR checks the tilling depth of a land application unit in relation to the depth of application that is calculated from inputs by the user. Please comment on all the checks in IWAIR. Do these checks capture unrealistic entries? If not, recommend an alternative.

They seem appropriate; I have not found any that seem unrealistic.

17. IWAIR can model the risks for 95 constituents (volatiles, semi-volatiles, and mercury.) These are the chemicals that were selected by OSW to model in a study, Air Characteristics Study that evaluated the potential direct inhalation risks from certain waste management units. The chemicals were selected for the Air Characteristics Study based on their potential to generate a risk via the inhalation pathway. Are there other chemicals that are commonly used in industry that should be added to the list of constituents considered in IWAIR?

As mentioned above, the only additional constituents that might be worth considering are particulate matter smaller than 2.5 micrometers in diameter. These can be generated in the atmosphere associated with VOC emissions or, I assume, could be directly emitted from the waste facility. Further, they might be so small that they would not be controlled by conventional particulate controls required for the facility. I am not an expert in this area so it might be appropriate to get an opinion from someone who is.

18. IWAIR will calculate the additive risk from the carcinogens. Considering additive risk for non-carcinogens is more uncertain due to target organ or multiple organ effects. Should a means for adding together the non-carcinogens be added to IWAIR? If so, please suggest a method.

This question is outside my area of expertise; I am not qualified to answer it.

19. Are the risks appropriately characterized for the cancer and non-cancer risks?

This question is outside my area of expertise; I am not qualified to answer it.

20. Review and comment on the Newton-Raphson Method used in back calculation approach in IWAIR.

Going backward from an acceptable risk to determine allowable loading, is a less determinate problem than the forward calculation, because waste can be partitioned in the aqueous phase (in soil water) or if above the soil saturation limit, in the oily phase. Simply doing the calculation can result in physically unrealistic results. To ensure this does not happen, a conventional iterative tool to locate the value of a numerically defined function of a parameter assumes at a particular value of that parameter. The numerical method (the Newton-Raphson method) is conventionally used for this sort of application.

21. Comment on the ease-of-use and logic of IWAIR.

It is appropriate for the audience intended. The model is very easy to use, its logic is well identified and appropriate given the objectives of for its design.

22. Comment on the nature of the instructions within the program. Are they clear and easy to understand?

They are clear and easily understood.

23. Comment on the layout of the user-interface screens. Are all easy to use and read?

All are easy to use and are well laid out. I would suggest adding a dialog box associated with the Screen 1 selection of the nature of the Waste Management Units. Upon selection of one of the three options a box could pop up indicating the sort of information about each that is contained on page 3-2 and the box on page 3-3 in the User's Guide.

24. Comment on the presentation of results. Are they consistent and easy to understand?

Results are presented clearly and are easily understood. I identified a typographical error on the Results screen (Screen 6), if one seeks to enter alternative health benchmarks, the dialog box that pops up has health spelled incorrectly.

25. Comment on the ease of installation and file manipulation (saving and retrieval?)

Installation was very easy to accomplish; it only takes few seconds. Instructions are clear and straightforward even for someone not accustomed to lading new programs.

26. Comment on the logic and clarity of the documentation. Were any important points, assumptions missing or inadequately explained?

Documentation is logical and straightforward. I did not notice anything that was missing or inadequately explained.

27. Comment on the structure of the user's guide. Is it easy to follow? Are there any inconsistencies with the software?

In general, the User's Guide is well structured, it is easily read and understood. I found no inconsistencies in the software. However, one area I found that could be improved is Section 6, Example Calculations. While this section provides a sort of simple example of how the calculation is conducted, it does not lead one through a detailed calculation referring to the software. For example, it does not include any discussion of the selection of data required for inputs to Screen 3A,B,C or D. For the example, Screen 3B must be completed but only one of the required parameter values (Landfill surface area) is specified. I found these two examples to be confusing because of this and less than helpful.

28. Comment on the readability of the user's guide. Can it be used by an individual without a lot of air modeling experience?

In my opinion, the user's guide is easily readable. Someone unfamiliar with air quality modeling can understand it.

29. Comment on the structure of the Technical Background Document. Is the modeling approach and logic used for development clear?

The Technical Background Document is easily read and easily understood. The modeling and its logic are clearly presented.

30. Is there sufficient explanation concerning the structure and assumptions in the model? What else should be described?

I think there is sufficient explanation of the approach and do not think any additional explanation is needed.

31. Comment on the readability of the Technical Background Document. Is it written at a level appropriate for someone with some environmental training and modeling experience?

The Technical Background Document is written at an appropriate level. It is appropriate for someone with an environmental background and some familiarity with environmental modeling.

In conclusion, I believe the approach taken by EPA's Office of Solid Waste to characterize the health risks associated with volatile air emissions from industrial waste management facilities is sound. The approximations made in developing this model are appropriate to the purposes for which the model is designed. Although, I have suggested a few places where I believe the model could be improved, I am confident that it could be used in its present form for its intended applications. The suggestions I have made, therefore, might best be addressed in a later release or revision after a few years of practice with the current version.

August 20, 1999

Mr. Eric Ruder
Industrial Economics, Inc.
2067 Massachusetts Avenue
Cambridge, Massachusetts 02140

Re: Peer Review of the IWAIR Model
PN 3153-1

Dear Mr. Ruder:

Under U.S. Environmental Protection Agency (EPA) Contract No. 68-W6-0061, Work Assignment No. 1-38, and under Subcontract Agreement No. 1004-30 with Industrial Economics, Inc. (IEC), Environmental Quality Management, Inc. (EQ) was to conduct a peer review of the Industrial Waste Air Model (IWAIR) and associated documentation. As set forth in the Peer Review Charge, EQ was to specifically review the emission algorithms used in the model.

Mr. Craig S. Mann of EQ conducted the peer review. The following represent the findings and recommendations of this review. These are organized by specific categories and questions found in the Draft Charge to Reviewers provided by IEC. For the sake of brevity, these questions are not repeated herein. The major conclusions and overall concerns about the IWAIR model are summarized at the end of this letter.

<u>I. Overall Model Performance</u>

1. The IWAIR model seems to offer a reasonable mathematical approach for estimating volatile emissions from the four types of waste management units (WMUs) included in the model. As to the accuracy of the emission models, no empirical data are offered in the *Industrial Waste Air Model Technical Background Document* (TBD) for comparison. Brief discussions of empirical studies are offered in the *Air Emissions Models for Waste and Wastewater*, U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-453/R-94-080A, November 1994, hereafter known as EPA (1994). This document is considered to be the background information document for the EPA CHEMDAT8 emission model; all of the emission equations used in the IWAIR model are taken from this document. A cursory summary of the results of these empirical studies can be found in Appendix A of EPA (1994). The author is correct in his assertion of a paucity in empirical studies with which model estimates can be compared. Therefore, this reviewer cannot make any judgements about the accuracy of the IWAIR emission models.

2. When forward calculating risk, the IWAIR model calculates the emission rate, the dispersion factor, and the resulting incremental risk and/or hazard quotient. These values would be sufficient for determining the need for emission controls if the need is based solely on risk. It would also be advantageous if the model listed the ambient air concentration at the receptor. These data could

then be used to compare the estimated exposure point concentration to regulatory acceptable air concentrations (e.g., State air toxics criteria). It must be remembered, however, that the present dispersion factors calculated by IWAIR represent annual average values only and cannot be compared with regulatory acceptable ambient concentrations based on less than an annual average (e.g., 1-h ave., 24-h ave., etc.). If dispersion factors could be produced for less than annual average exposure periods, the model would be much more useful as a screening tool for directly comparing predicted air concentrations to regulatory acceptable air concentrations. One option for calculating less than annual average dispersion factors would be to use the EPA SCREEN3 dispersion model to estimate worst-case 1-h average air concentrations at the appropriate receptor distance. From these data, the 1-h average concentrations may be converted to 3-h, 8-h, or 24-h averages using the EPA dispersion correction factors found in the *Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants (Revised),* U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-454/R-92-024.

3. By neglecting particulate matter emissions, the IWAIR model may be missing a significant portion of the risk, especially with respect to nearby offsite receptors. Significant potential particulate matter emission sources include wind erosion from undisturbed soils and waste handling activities. Other significant potential particulate matter emission sources include soil or waste storage piles which tend to dry out relatively quickly and are situated above the soil surface and thus exposed to higher wind velocities. In addition, movement of waste material via conveyor belts and drops to storage piles can also result in significant particulate matter emissions. These emissions, in some cases, may result in the majority of exposure to semivolatiles adsorbed to the waste organic carbon or the exposure to nonvolatiles (e.g., metals). At the present time, emission models for these types of sources can be found as empirical models in the *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, and Supplements (AP-42),* Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1985. It should be understood, however, that use of many of these models requires choosing justifiable default values for input parameters or requires the model user to input site-specific data. Selection of justifiable default values for these types of input parameters would not be a simple matter and could significantly increase the complexity of constructing particulate matter emission algorithms for the IWAIR model. Presently, the IWAIR model does not estimate particulate matter emissions because these emissions are assumed to be controlled. It has been my experience at both Superfund and RCRA sites that this assumption is not always valid. Indeed, fugitive particulate matter emissions from waste handling and processing may exceed the controlled emissions from the WMU.

II. Specific Model Features

4. The ability of the user to change the emission rate, dispersion factors, and toxicity benchmarks definitely enhances the usability of the model. This, of course, assumes that any values entered by the user can be justified and evidenced by referenced calculations or with measured data that has been acquired using a proper quality assurance project plan. The correct use of referenced calculations for user-input values should in no way be trivialized. Even the most accepted mathematical models may be misapplied or simple calculation errors may give, in some cases, grossly inaccurate results. Allowing the user to enter his/her own values may increase the flexibility of the model but will require regulatory staff to verify all calculations and the

appropriateness of input parameter values. This may impose a significant burden on the regulatory community.

9. The emission calculations used in the IWAIR model are taken from EPA (1994). The calculations for active landfills, land application, and waste storage piles incorporate both evaporation of the liquid phase contaminant from the waste surface and diffusion of the contaminant through the porous medium of the waste. Surface evaporation is calculated depending on the averaging time over which the emissions occur. For short time periods, emissions from both surface evaporation and diffusion are calculated; for longer time periods, diffusion alone is considered. For surface impoundments (both quiescent and agitated), emissions are modeled as a function of the two resistance film theory. These calculations assume a well-mixed system with emissions dependent on chemical properties (e.g., Henry's law constant) and system properties (e.g., degree of surface agitation, windspeed, etc.).

   Using the equations in EPA (1994), I tried to duplicate the solutions to the emission rates predicted by the IWAIR model for each type of WMU. Except for emissions from surface impoundments, it was not possible to directly compare results in that the emission solutions provided by IWAIR are time-averaged values while the example problems given in EPA (1994) evaluate instantaneous emissions at a specified time. Given this constraint, I used a trapezoidal approximation of the integral to estimate the time-averaged emissions over the time of calculation (t_{calc}) as specified in the IWAIR TBD. Using this technique, same order of magnitude results were achieved with some comparisons within a factor of two. In addition, emissions based solely on diffusion were compared with other diffusion models; results were nearly identical. From the IWAIR TBD and User's Guide, it was not possible to determine exactly how emissions were integrated over time. For example, were the time-averaged emissions evaluated using a trapezoidal or Simpson Rule approximation of the integral? For contaminants in residual phase, were the mole fractions recalculated at the end of each time-step interval or were the mole fractions assumed to be constant with time? If the mole fractions are recalculated at each time-step, the relationship between waste concentration and equilibrium vapor concentration is not linear with time. If indeed the change in the mole fractions are accounted for in the emission calculations, this would explain why the Newton-Raphson method was used to evaluate risk as a function of waste concentration.

   I found the explanations and the discussions of the relevant equations in EPA (1994) to be rather difficult to follow. It should be expected that someone with limited experience with emission modeling would have a considerable degree of difficulty understanding not only the theory but the hierarchical procedures required to derive a solution to the emission calculations. To help reduce potential confusion, my recommendation would be to include the appropriate sections of EPA (1994) within the IWAIR TBD. These sections, however, should be rewritten in a sequential order with a minimum of theory; the IWAIR TBD could refer the user to EPA (1994) for a more thorough explanation of the theoretical considerations.

The following represent questions the answers to which were not apparent in either EPA (1994) or in the IWAIR TBD or the User's Guide.

- According to the modeling assumptions in the IWAIR TBD, biodegradation is modeled for all emission sources except active landfills. In EPA (1994), however, biodegradation is not modeled for waste piles because no significant biomass is presumed to be available. In addition, the waste is assumed to be toxic to any potential biomass. An explanation of this apparent discrepancy could not be found in the IWAIR TBD.

- On page 8-40 of EPA (1994), the waste pile is assumed to be flat with a uniform height of 100 cm (1 m). This is consistent with the emission model geometry of a flat infinitely deep slab emission source as described on page 7-4 of EPA (1994). It is not clear in the IWAIR documents whether this is also the assumed pile height for purposes of estimating emissions in that the model asks for both the pile height and area. For the purposes of dispersion, waste piles are evidently modeled as elevated area sources with heights above grade of either 2 or 5 meters. Because the model asks the user for both the area and height of the waste pile, it should be made clear what geometry is used for both emissions estimation and dispersion. When I came to this section of the model, my first assumption was that a storage pile was configured as a right cone, not a flat slab. This potential for confusion concerning pile geometry could be eliminated with an explanation in the IWAIR TBD.

- It is not clear in the IWAIR documentation how the time-averaged fraction emitted to air is calculated. It is assumed that the instantaneous fraction emitted to air at time = t for active landfills, waste piles, and land application is calculated with the appropriate equations from Table 7-3 of EPA (1994) depending on the values of $K_v t$, F_a, $K_v t_b$, and $K_d t_b$. To estimate the time-averaged emission rate or fraction emitted to air, the instantaneous emissions must be integrated from time = 0 to time = t. Because a numerical estimation of the integral is evidently employed, an explanation of the numerical technique used should be given in the IWAIR TBD.

- It is clear in the IWAIR TBD that the windspeed and temperature data retrieved by the model for the applicable meteorological station represent annual average values. It is presumed that the windspeed is used in calculating the gas phase mass transfer coefficient and that the temperature is used to calculate the contaminant vapor pressure assuming that the waste temperature has come to equilibrium with the ambient air temperature. If this is the case, it should be confirmed in the IWAIR TBD.

- The emission model for surface impoundments will not allow the user to enter initial aqueous contaminant concentrations greater than the solubility limit. It is therefore assumed that the model does not include algorithms for estimating emissions from oil film layers at the surface of the impoundment as specified in Section 5.7 of EPA (1994). It has been my experience that this situation is not uncommon. Not including oil film layer emission calculations seems to be a model shortcoming.

III. Parameters Used for WMUs

12. In the case of diffusion-limited emissions, waste air-filled porosity is the most sensitive nonchemical-specific model parameter. The default values given in Tables 2-1, 2-2, and 2-3 of the IWAIR TBD assume that one half the total waste pore space is air-filled. This

assumption seems relatively conservative which would be appropriate for a screening-level emission model. The default value of the degradation rate of total organics given in Table 2-4 of the IWAIR TBD is 19 mg/g. On page 7-38 of EPA (1994), the ratio of the aqueous biorate for benzene (19 mg VO/g biomass-h) is divided by the measured decay constant for benzene in clay loam soil of 0.034 day^{-1}; this results in a value of 0.00179. EPA (1994) goes on to say that the value of this ratio (0.00179) is used for all compounds to convert aqueous biorates to decay constants for use in the land treatment model. The decay constant (t_b) in units of seconds is thus calculated for any contaminant by: t_b = 86,400 s/day ÷ (0.00179 x B) where B is the biorate constant of the contaminant in units of mg VO/g biomass-h. It is assumed that the default degradation rate of total organics in Table 2-4 of the IWAIR TBD is the value for benzene but more accurately should be given in units of mg VO/g biomass-h. If this is the case, the value of 19 mg/g-h is at odds with the default biorate from page 7-40 of EPA (1994). Here the default value is given as 40 mg/g-h. Finally, the default value of the degradation rate is tied to an assumption that all possible wastes for land application (and thus waste piles) are similar to benzene in biodegradation potential. Some wastes, however, may not fit this assumption (e.g., halogenated wastes) and the toxicity of the contaminants relative to the biomass may be quite different.

15. The IWAIR model assumes that the total organics in the waste are comprised of a set of relatively volatile constituents and another set of less volatile constituents. The model treats the latter as a single entity with a default molecular weight. This approach apparently is an extension of the assumption that the waste is either petroleum waste or an equivalent oily waste. If, however, the waste is comprised of only a few contaminants of relatively equal emission potential, the best way to determine the aqueous phase equilibria is by calculating the effective solubility of each contaminant. Concentrations above the effective solubility signify the presence of a residual phase and equilibrium vapor concentration would be calculated by Raoult's law; concentrations below the effective solubility require the use of the Henry's law constant. Phase equilibria in a porous medium such as in soil or solid waste is more complicated and requires a relatively sophisticated solution. The approach taken in the IWAIR model is appropriate for the types of wastes for which it was first applied (e.g., petroleum-based wastes and other oily wastes) but may not be applicable for all situations. When a residual or pure component phase exists, the IWAIR model calculates the equilibrium vapor concentration as a function of the liquid mole fraction, the vapor pressure at temperature, and the molecular weight using Raoult's law and the ideal gas law. Over the time-averaging period, however, the model should consider changes in the mole fraction of each constituent as the more volatile components are emitted at a faster rate. At this time, I could not determine if the mole fractions are recalculated at each time-step. Regardless, calculation of the equilibrium vapor concentration at the transition point between the residual and aqueous phases can produce a very significant discontinuity. Numerical solutions to multicomponent phase equilibria which minimize this discontinuity exist but require much more sophisticated mathematical calculations. These calculations could be coded into Visual Basic for use in IWAIR, but would require considerable resources.

When waste concentrations are less than the solubility limit or less than approximately 10 percent total organics, the model calculates vapor equilibrium based on the Henry's law constant. Unlike residual phase equilibrium, the Henry's law constant is used only at standard conditions (25^{o}C and 1 atmosphere of pressure); no adjustment is made for system temperature. Correcting the Henry's law constant for temperature can have a significant effect on vapor equilibrium. Correcting for temperature has the greatest effect on semivolatiles. For example, reduction of the solid waste temperature from 25^{o}C to 10^{o}C reduces the Henry's law constant of benzene by about 50 percent; this same temperature change reduces the Henry's law constant of a typical semivolatile by perhaps one order of magnitude. Data could be included in the IWAIR model to make this adjustment. The required chemical-specific data includes the enthalpy of vaporization at the normal boiling point, the normal boiling point, the critical temperature, and the B and C Antoine coefficients.

16. It appears that the built-in checks ensure that the model captures unrealistic entries. I did, however, experience one problem. I entered ".5" and ".25" as values for total porosity and air-filled porosity, respectively. The following message was subsequently displayed: "Data type mismatch, e.g., text entered when number expected." After re-entering these values as "0.5" and "0.25", the same message reappeared. I could not eliminate this message without restarting IWAIR.

IV. Risk Assessment

20. If the air concentration is directly proportional to the initial waste concentration, the relationship between risk and waste concentration is linear. This is true if the waste concentration is below saturation (i.e., the solubility limit or saturation in soil/waste). This is not true, however, if the waste concentration represents a residual phase. In this case, the mole fraction of each constituent is variable with time and the relationship is nonlinear. If the relationship is nonlinear, the Newton-Raphson method is a reasonable approach for estimating the relationship between air concentration and waste concentration.

V.The Quality of the Software and Documentation

21. The IWAIR model is easy to use and logical in its presentation and sequence.

22. The instructions in the program are clear and easy to understand.

23. All of the user-interface screens are easy to use and read.

24. The presentation of modeling results are consistent and easy to understand.

25. Model installation and file manipulation are simple.

26. See the answers to Question 9.

27. The User's Guide is relatively easy to follow; I could find no inconsistencies with the software.

28. As to whether or not the information and procedures in the User' Guide can be understood and followed by the general public, my first reaction is yes, however, this initial reaction is subjective. Perhaps testing the model with a representative sample of people would be useful.

29. As stated in the response to Question 9, the TBD does not include the theoretical basis for the emission calculations nor the actual equations used by the model. I think it might be useful to include at least the appropriate equations from EPA (1994) within the TBD and refer the user to EPA (1994) for a more detailed discussion of the theory behind the emission algorithms.

30. All of the assumptions and limitations of each emission model should be included in the TBD. For example, none of the emission models deplete the emission source over time, i.e., the initial mass of contaminant is not reduced. Diffusion-based models do, however, account for reduced emissions as a function of time due to the increased diffusion path length. It is important for the user to understand model assumptions and limitations to be able to better apply the IWAIR model to site-specific conditions. I think it would also be helpful to the user to understand the relative uncertainty and sensitivity of individual model input parameters. This could be done by including a table for each model with a column for relative uncertainty (e.g., high, medium, low) as well as a similar column for model parameter sensitivity. In addition, a table might be included that shows the effect of changes in individual input parameter values as they relate to final incremental cancer risk or hazard quotient. This would give the user an idea of the results of using input parameter values other than the default values.

31. The TBD is well written and suitable for someone with limited environmental training and modeling experience.

<u>Overall Concerns</u>

The following represent the major concerns identified in the draft version of the IWAIR model and documentation.

- From reviewing the documentation, it is my impression that the biodegradation algorithms rely primarily on empirical studies of municipal waste water treatment and treatment of petroleum related wastes. Biorate constants for individual contaminants may not be applicable for some industrial waste situations. High initial contaminant concentrations as well as the types of contaminants (e.g., halogenated compounds) that may be present in these systems may be toxic to naturally occurring bio-organisms or may require inoculation of the waste with specially engineered microbes. Therefore, the default chemical-specific biorate constants as well as the default biomass concentrations may not be applicable resulting in artificially high rates of removal. At the present time, the state-of-the science in regards to biodegradation is still evolving. The kinetics may or may not be first-order in nature for different contaminants and mixtures of contaminants. By relying solely on empirical data from a relatively narrow range of contaminants and bio-active processes, the degradation constants used by the IWAIR model may not be applicable for all industrial waste applications. See the response to Question 12.

- Equilibrium vapor concentration when a residual phase is present is based on Raoult's law and the ideal gas law. It is not clear in the IWAIR documentation as to whether the mole fractions are recalculated at each time-step of the emission models. In addition, the IWAIR documentation does not explain what procedure is used to calculate the time-averaged emissions (e.g., trapezoidal integration, Simpson Rule, etc.). If the change in the mole fractions are recalculated, this would explain the necessity for using the Newton-Raphson method for determining the nonlinear relationship between risk and waste concentration. The calculations need to be documented in the IWAIR TBD. See the responses to Questions 9 and 15.

- When applying Raoult's law to the calculation of the equilibrium vapor concentration, the vapor pressure of each contaminant is corrected for system temperature using the chemical's Antoine coefficients. The same cannot be said for the contaminant's Henry's law constant. Correction of the Henry's law constant for temperature requires a relatively simple calculation but also requires additional chemical properties data. Consideration should be given to including such a correction. See the response to Question 15.

- Documentation of the emission model equations, assumptions, and limitations are found in three separate documents. This can be confusing for the IWAIR model user, especially if the user has limited modeling experience. Consideration should be given to including at least the emission equations in the IWAIR TBD as well as the complete list of model assumptions and limitations. The sequence of equations used to calculate the emissions should be in the correct order without requiring the user to back-track through the sequence. See the responses to Questions 9 and 29.

- The emission model for surface impoundments does not include the equations in EPA (1994) for estimating emissions from oil film surfaces. These equations estimate emissions from residual phase contaminants floating on the surface of the impoundment. This is likely to occur for some industrial waste applications, therefore it would be prudent to include these algorithms in the IWAIR model. See the response to Question 9.

- All assumptions and limitations of each emission model should be included in the IWAIR TBD. In addition, consideration should be given to inclusion of simple tables for specifying the relative sensitivity and relative uncertainty of each model input parameter value. This would help the user to determine how the use of parameter values other than the default values would effect model outcomes. See the response to Question 30.

Sincerely,
ENVIRONMENTAL QUALITY MANAGEMENT, INC.

Craig S. Mann

PEER REVIEW OF EPA'S INDUSTRIAL WASTE AIR MODEL
Comments by Art Schatz
Parsons Engineering Science, Inc.
Prepared for Industrial Economics, Inc.

I have reviewed the USEPA's Industrial Waste Air Model (IWAIR) and two companion documents: the Technical Background Document and User's Guide. My evaluation has consisted of reading the two documents to become familiar with the model's purpose, basis and capabilities and running various test cases with the model to observe its performance and output. In addition, I performed one ISC3ST modeling simulation for comparison with the IWAIR model.

My comments are organized as follows. First, I summarize my overall impressions of the IWAIR model. Next, I have responded to many of the specific questions posed in the Charge to Reviewers for this project. I have tried to focus on the dispersion aspects of the model, as requested. Finally, I discuss several of the test cases and the ISC3 analysis that I performed, and highlight some of the problems observed with the model.

GENERAL OBSERVATIONS

The IWAIR model has the potential to be useful as a conservative screening model for waste management units (WMUs). The general applicability to a range of sources and the level of conservatism of IWAIR are similar to the approaches many State environmental agencies use to screen emission sources for toxic air pollutants as part of their air permitting process. These agencies often have acceptable emission rates based on toxicity and simplified dispersion model-based factors in their policies or regulations to evaluate the health risk from emission sources.

IWAIR is generally easy to use and clearly documented. However, as discussed in the comments below, there are some inconsistencies between the model and documentation, some apparent errors and bugs in the model.

RESPONSE TO SPECIFIC QUESTIONS

1. Overall Model Performance

Model Goals:
- Reasonable estimates of risk from a specific unit for direct inhalation
- Simple, so can be run by users with different levels of knowledge and experience, including the public
- Capable of running with very little data (enables public to use)
- Flexible; user can enter alternative emissions data, dispersion data, and/or toxicity benchmarks

1.a. Is IWAIR an appropriate tool? Does the model provide a reasonably accurate representation of risk from a unit?

IWAIR clearly meets the final three stated goals, as summarized above. It is simple enough for the user to navigate and enter inputs in the appropriate form. It can be run with very little real data. And, IWAIR has the ability to accept emission rates, dispersion factors and toxicity benchmarks provided by the user in lieu of the embedded estimation approaches (i.e., CHEMDAT8, ISC3ST-derived dispersion factors, and built-in RfCs, URFs and CSFs).

The most important question here is whether or not IWAIR provides reasonable estimates of risk via inhalation for a given waste management unit. This is a difficult question to answer with much certainty. The ease of use of this model and the ability of users with little or no experience with emissions estimation, dispersion modeling or risk assessment to enter numbers makes this model extremely susceptible to “Garbage In – Garbage Out”. While this model may be useful for preliminary screening of facilities for risk, the Users Guide, and perhaps an initial model screen, should caution the user about the large uncertainty inherent in this model and the limits of simulations run with very little data.

1.c. Does the model perform well over a range of input values and scenarios?

I conducted only a limited sensitivity analysis of the model to ranges of input values and general performance evaluation. In many cases, IWAIR’s results varied with individual parameter value changes as expected. As discussed below, there appear to be calculation problems that need to be corrected.

1.d. How can the model be improved?

This model needs continued review and work to correct calculation errors, output presentation errors and other bugs.

2. The intention of IWAIR is to help determine whether or not emission controls should be placed on a waste management unit (WMU). Are IWAIR results appropriate for this analysis? What results would be more appropriate to determine if emission controls are necessary?

IWAIR may be useful as an initial step toward assessing the need for controls on a specific WMU. IWAIR provides the chemical concentrations in waste and the emission rate for each chemical associated with a risk level for a WMU. However, IWAIR cannot perform this calculation for total cancer risk from a group of chemicals (there would be many solutions to this problem). To the extent that IWAIR shows how one might reduce concentrations in waste, or emission rates, IWAIR provides useful results.

However, there is so much uncertainty and conservatism built into this model, that it is unlikely that IWAIR would be used directly to evaluate controls. IWAIR may serve as a simple Tier 1 screening tool. But if IWAIR suggests unacceptable risks, the next appropriate step is more site-specific data collection and more site-specific and refined modeling. For example, the IWAIR dispersion analysis does not consider wind direction in estimating receptor risks. But, at any given distance, true receptors may be present in only one direction. This type of site-specificity must be considered before making control recommendations. Similarly, in many cases, waste characterization and emissions should be further evaluated before evaluating controls, since emission models may greatly overestimate emissions.

3. Particulate emissions are assumed to be negligible and are not modeled. Only direct inhalation is evaluated (no secondary pathways via deposition). Is this adequate for the chemicals considered?

If particulate emissions are truly controlled and minimized by WMUs, then the “no particulate emission” assumption is appropriate. It is certainly conceivable that landfills or land application units might release fugitive dust containing chemicals. In my recent experience assessing inhalation exposures to fugitive dust from soils at CERCLA sites, this pathway has not contributed significantly to risk. In general, from surface impoundments and land application units especially, I would expect volatile emissions to be a greater concern than particulates. Therefore, the emphasis on volatile emissions in this model is appropriate, especially with the explicit assumption that particulate emissions are adequately controlled. Nothing precludes the investigator from exploring risks from particulate emissions as a special case, albeit with a different model, should this pathway be a concern.

However, given that this model assumes that particulate emissions are negligible, the list of chemicals considered by IWAIR includes some barely volatile compounds. Compounds with very low vapor pressures (for oily wastes) and very low Henry’s Law Constants (for aqueous wastes) would be expected to have very low vapor emissions from any of the WMU types considered by IWAIR. Examples of some of these compounds include benzo(a)pyrene, 7,12-dimethylbenz(a)anthracene, phthalic anhydride, and benzidine. These compounds would be much more likely to be associated with particulate emissions than vapor emissions. It appears that toxicity of chemicals may have been considered without regard to chemical volatility in developing the list of chemicals included in the IWAIR database. Regardless of toxicity, nonvolatile compounds would be expected to pose little risk.

II. Specific Model Features

4. Does the flexibility to change emission rates, dispersion parameters, and toxicity benchmarks make a more robust tool?

The ability to change parameters in the model is a useful and necessary aspect of this model. This flexibility allows the user to best simulate reality, explore the sensitivity of results to ranges of parameter values and explore the impact of changes in the source that might be considered to control emissions. As with all models, input parameter values need to be selected knowledgeably.

5. Is the approach based on previously calculated dispersion factors reasonable?

For a first-cut, conservative estimate, the use of generic dispersion factors such as those embedded in the IWAIR model is reasonable. I make this statement with considerable reservation, since I fear that in many cases the results of such an analysis might severely overestimate risk. The matching of a regional meteorological station to represent the dispersion regime of every WMU in a geographical area is fraught with uncertainty. Local micrometeorology in the vicinity of a facility can differ vastly from that measured at a regional airport. The lack of directionality in the IWAIR analysis may also lead to overly conservative results in many cases. There is probably more variability in the predicted concentrations at a given distance from a source by direction, than there is among the maximum predicted concentrations at each distance among the 29 meteorological stations included in the IWAIR database.

The geographical matching may give some users the impression of greater accuracy than is warranted. The difference between the highest and lowest UACs among stations listed in Tables 3-4 and 3-5, for instance, is only a factor of 2. This difference is small in comparison to the uncertainties inherent in (1) the emission estimates generated by models such as CHEMDAT8, and (2) the toxicity benchmarks used in risk analysis. Given these facts, I would recommend considering using a single, conservative dispersion factor based on a statistical analysis of the highest UACs from each of the 29 meteorological stations (or more stations could be used). The upper 90% confidence limit about the mean of these values would be an appropriate, conservative estimator. Use of such a single value for all locations would give conservative results without giving the impression of location-specific accuracy for the results of these screening analyses.

Alternatively, I would like to see a comparison of windroses from each of the 29 "regional" meteorological stations to each of the other major reporting stations in each region, to get a better sense of (1) the representativeness of the selected stations, and (2) the actual variability among the stations by region.

6. Is the number of representative meteorological stations sufficient?

As indicated to my response to Question No. 5, I am skeptical about the accuracy of assigning any of the "representative" meteorological stations to any other location. I like the approach of running ISC3ST to develop dispersion factors. The Soil Screening Levels study document (EQM and Pechan, 1993) reportedly claimed that the 29 meteorological stations predicted mean dispersion from a population of 200 stations with 95% confidence. Assuming this statement is correct (I have not reviewed the original study report and cannot independently corroborate), then the 29 stations used are probably adequate.

7. Are the dispersion modeling assumptions appropriate (flat terrain, rural vs. urban, square area source geometry, no depletion mechanisms)?

Yes. For a screening model, each of the above assumptions is appropriate in the absence of any site-specific information. The user may substitute dispersion factors developed external to IWAIR if complex terrain or urban environs are more appropriate. Since particulate emissions are not considered by IWAIR, wet and dry deposition should be negligible (particularly for a screening analysis).

8. Have the boundaries surrounding a meteorological station that assign a region to a station been assigned appropriately?

See response to Questions 5 and 6.

9. Is CHEMDAT8 an appropriate emissions model?

The emission sources being considered in IWAIR are extremely difficult to model accurately. Landfill and surface impoundment emission models in general consider a limited number of parameters in calculating emissions. These sources and their emission mechanisms can be very complex. My impression is that a limited amount of validation has been performed on these types of models, and the validation experiments represent a limited set of conditions that may not represent a source of this type at another time or under different meteorological conditions. Models such as CHEMDAT8, in my opinion, produce a scientific emissions guess.

My impression of CHEMDAT8, based on technical papers I've seen, is that it tends to overestimate emissions. This overestimate may be quite large in some cases (an order of magnitude). In the handful of comparisons to other modeling approaches that I explored as part of this review, CHEMDAT8 always predicted higher emissions. CHEMDAT8 has the capability to produce estimates for the range of WMUs being considered by IWAIR; other available models may be able to only handle one type of WMU (such as landfills or wastewater units). Given its apparent conservatism and its ability to handle all WMU types, CHEMDAT8 is an appropriate screening tool. I recommend that the conservatism of CHEMDAT8 be emphasized in the IWAIR documentation, to discourage a false sense of accuracy for the estimates produced.

10. Are there better tools or modeling approaches for the purpose of the location-adjusted analysis?

For a screening-level assessment, the current approach used in IWAIR to infer location-specificity is probably as reasonable as any alternative. As discussed above, I am skeptical about the representativeness of data from a regional meteorological station for another location as far as 500 miles away. Given all the uncertainties of the dispersion analysis and the even greater uncertainties associated with the emissions and risk calculations, I recommend that EPA consider abandoning the location-specific concept altogether.

A more accurate approach would be to use the nearest, appropriate and available meteorological dataset for each site, and consider wind direction and location of true receptors in estimation of risk. Obviously, this approach would require site-specific data collection and analysis for every site, and would be more resource-intensive than I believe EPA desires.

11. Is the "interpolation of source areas" routine an appropriate way to estimate dispersion factors for all source areas?

The current IWAIR method for estimating dispersion factors for any surface area relies on linear interpolation between two areas with known dispersion factors (based on ISC3ST model runs). This approach has the advantage of being relatively simple, both for the user to understand and for the program to compute. Based on my visual analysis of a plot of UACs vs. Surface Areas for 2-meter high waste piles (Little Rock data), it appears that the linear interpolation may underestimate the UAC by up to 20% in some regions of the graph. For example, if one looks at Figure 3-6, page 3-16 in the Technical Background Document, it appears that the curve of the true line between the points at 10,000 m^2 and 100,000 m^2 would lie above the straight line that connects these points. I consider this amount of error to be small compared with other uncertainties of the IWAIR model.

I can suggest two better approaches. The first is to run ISC3ST for more areas to require less linear interpolation between adjacent size areas. The second is to apply the linear interpolation routine to the logarithms of the adjacent areas. This approach tends to equalize the distance between adjacent known points on the UAC vs. Area curve, and appears to reduce the error to about 10%. For the waste piles, this approach slightly overestimates emissions.

IV. Risk Assessment

19. Are risks appropriately characterized for cancer and non-cancer risks?

I checked the calculations of Cancer Risk and Hazard Quotient in several IWAIR model runs. I was able to duplicate the Hazard Quotient calculation, but always calculated different cancer risks.

For cancer risks, I used data in the printed model output to check the risk calculations, following Equations 6-1 and 6-2 on page 6-1 of the Technical Background Document. In each case, I evaluated a resident receptor. I calculated the summation term in Equation 6-2 [sum (IR_I x ED_I / BW_I)] from the values in Table 4-1 (page 4-2) of the Technical Background Document to be 9.07 m^3-yr/kg-d. In both cases evaluated (vinyl chloride from a landfill and benzene from a surface impoundment), my calculated value was 9.2 times the IWAIR-produced risk value. There appears to be an error in the cancer risk calculations performed by IWAIR. A detailed explanation of these calculations and related model run reports are provided in Attachment A to this report.

I have also noticed that in seemingly duplicate model runs, IWAIR has sometimes produced different risk results. I can't explain these results, but suggest that the model calculation code be reviewed for bugs. [A paper copy of the output from these duplicate model runs has been submitted to EPA (see Attachment B). They are not available in electronic format.]

The printed IWAIR results report documents the waste concentration, emission rate, dispersion factor and final risk results. However, the exposure concentration in air ($\mu g/m^3$) is never printed. This would be valuable information to provide the user.

V. Quality of the Software and Documentation

21. Ease-of-use and logic of IWAIR

In general, I found IWAIR easy to use. The flow from location selection to WMU description, chemical selection, emission calculation, dispersion calculation, and risk calculation is logical.

22. Instructions within the program

I found the instructions within the program easy to follow. However, I am very familiar with each step of the modeling process. I would expect that some users would find some of the parameters required to run CHEMDAT8 unfamiliar and difficult to estimate. For example, in the case of an aerated surface impoundment, such parameters include Submerged Air Flow, Active Biomass, and Power Input to the Aerators. Also, the requirement to express all input parameters in metric units might hinder some users or lead to errors.

23. User interface screens

I found the layout to be easy to use and read.

24. Presentation of results

The results are reasonably easy to follow, although sometimes extraneous or incorrect information is reported (see comments on case examples run). I like the general format of the printed output, but found the requirement to continually re-enter certain information on sequential model runs cumbersome. The results screen needs a simple “Print” button.

25. Installation and file manipulation

IWAIR was easy to install. I had no problems saving and retrieving files.

26. Logic and clarity of the documentation

I found both the Technical Background Document and the User’s Guide to be generally well organized and easy to follow. I noted a few inconsistencies, missing pieces of information or errors, as listed below:

<u>Technical Background Document</u>

- Page 3-5, 1st paragraph. The last sentence says there are windroses in Appendix B. No windroses appear in the Appendix.
- Page 3-5, 4th and 5th paragraphs. These paragraphs will be difficult for most readers to understand. Technical references to Thiessen polygons, Bailey's ecoregions and conflation will be foreign to most readers. A simpler explanation of what was done is needed.
- Page 4-3, Section 4.3. The need for body weights for adults age 19-29 is specified twice. The reason that this age range is important for the model needs to be explained.
- Appendix D. This appendix discusses the sensitivity of ISC to the depletion option, source shape and orientation, and receptor location and spacing. While some of this discussion may inform and reassure some users, I found this to be level of analysis for these options to be misplaced. First of all, depletion is practically irrelevant for near-field dispersion of vapors – I found this discussion unnecessary. Source shape clearly influences area source emissions. So, for a simple screening model designed to fit many types of sources, a square area is an obvious neutral choice. I am much more concerned about misapplication of a "regional" meteorological data set to a particular source, and the effect of wind direction (which is totally ignored in this discussion), than any of these other factors that are covered in detail.

User's Guide

- Page 3-3. Text box with IWAIR Assumptions. Under Landfill Assumptions, the first bullet states that the active cell is modeled as being open for one year. This contradicts the Technical Background Document, page 2-9, which states that the active cell is modeled as open for t_{life}/N years. I believe the Background Document is correct.
- Pages 4-2 through 4-5, Figures 4-1 through 4-4. The headings of each text box need to be corrected so all letters appear.

OBSERVATIONS WHILE RUNNING THE IWAIR MODEL

Selecting the meteorological station. Once I've identified the appropriate meteorological station (by entering the zip code), I would like to be able to simply type in the name of the station in subsequent runs. It appears that the only options currently are to re-type the zip code or latitude/longitude coordinates. I also tried to pull down the map embedded in the program and click on the location of the station, but this doesn't work.

Model Output. Model results can be printed from the "File" drop down menu, however, this option may not be obvious to the user. The ability of this model to generate a report at the end of each run is critical for documentation. A simple report-printing button should be added to the final screen. The ability to save the results as a file would also be useful.

Facility, Date, User and Additional Information Screen. This screen, which pops up when the user selects the file - print option, documents useful information for each run. I like the way the data input screen is laid out, and the way this information is presented on the printed report. I suggest two improvements:

- Allow this information to be saved from run to run, so it doesn't have to be re-input every time
- For the "Date of Sample Analysis", have an automatic default value with the current date, that can be overridden by the user as an option.

WMU for CHEMDAT8 screen. On the WMU for CHEMDAT8 screen, temperature and windspeed values shown should be characterized as " *average* values for the Met. Station selected".

User Override of Emission Rate. I ran a Surface Impoundment test case where I input my own emission rate and dispersion factor (user override of CHEMDAT8 and built-in dispersion factors). At each input screen, I was required to enter a justification for the User Override Values. On the printed report, the dispersion factor justification was copied, but the emission rate justification was missing.

Dimensional Units in Output. There appear to be several errors in the units of various parameters as they are expressed on the printed output, as follows:

- For a landfill model, the chemical concentration is printed as mg/Liter, rather than mg/kg.
- The dispersion factor is printed as micrograms/m^3 per (gram/m^2-sec), rather than micrograms/m^3 per (*micro*gram/m^2-sec).

CASE EXAMPLES

Landfill Emissions.[4] I ran a prior landfill example for comparison with a landfill emission estimate done for an emission inventory at an industrial facility (pulp and paper mill). The emission inventory estimate was calculated using a method recommended in AP-42. I chose two compounds at random to model: ethylbenzene and vinyl chloride. The emission rate results from the two methods (IWAIR and AP-42) were somewhat different. IWAIR was more

[4] A paper copy of these model runs has been submitted to EPA (see Attachment C). They are not available in electronic format.

conservative (i.e., produced higher emission estimates), which may be appropriate for screening model. The specific factors that may contribute to the different results between these models were not evaluated for this example.

Example inputs:

Landfill area:	28,329 square meters (7 acres)
Lifetime:	2 years
Depth:	3 meters (a guess, actual unknown)
Number of cells:	24 (a guess, actual unknown)

Comparative results:

Compound	IWAIR	AP-42	Ratio, IWAIR:AP-42
Ethylbenzene	0.077 tons/yr	0.058 tons/yr	1.3
Vinyl Chloride	0.31 tons/yr	0.056 tons/yr	5.4

Problems for user:

- May be difficult to obtain landfill depth
- May be difficult to obtain number of cells

IWAIR model results are sensitive to the number of cells assumed. I compared example calculations where all variables were kept constant except the number of cells, which was varied between 24 and 12. The results for 24 cells were 1.4 times the 12-cell results. IWAIR assumes the entire mass of waste placed in each open cell is placed at the beginning of the interval. This assumption leads to the estimate of higher emissions for a greater number of cells (for a given mass of waste disposed).

Intuitively, I would expect a landfill with more cells to have lower emissions than one with fewer cells over the same time period. In the landfill with more cells, the cells have a smaller area and remain open for less time. Both of these factors should result in lower emissions. In all cases, the emission rate decreases with time as the chemical evaporates (IWAIR correctly models this aspect). So, if a cell remains open for two months, the emission rate is higher during the first month than the second month. If all of the waste is assumed to be placed in the cell at the beginning of the interval (as IWAIR does), then the average emission rate for a cell open for one month will be higher than the average emission rate for a cell open for two months.

The IWAIR assumption that all waste is placed in a cell at the beginning of the interval is unreasonable. If the capacity of a cell were filled on the first day of use, it would make sense to close the cell immediately and open a new cell for the next shipment of waste. A uniform disposal rate over the interval would be a more reasonable assumption. I believe that a landfill model with a uniform disposal rate would exhibit less sensitivity to the number of cells in the landfill.

Surface Impoundment Emissions.[5] I ran a surface impoundment example for comparison with a prior emission estimate done for an open API separator at a petroleum refinery. The prior estimate was calculated several years ago using EPA's SIMS model. In both cases, 6 compounds were modeled: benzene, ethylbenzene, n-hexane, naphthalene, toluene and xylene. The emission rate results from IWAIR were always higher than the SIMS results, although they are similar models.

Example inputs:

[5] A paper copy of this model run has been submitted to EPA (see Attachment D). It is not available in electronic format.

Surface Impoundment area: 182 square meters
Depth: 3.65 meters
Annual loading of waste: 935,000 cubic meters/year

Comparative results:

Compound	IWAIR	SIMS	Ratio, IWAIR:SIMS
Benzene	2.6 tons/yr	1.8 tons/yr	1.4
Ethylbenzene	4.9 tons/yr	2.6 tons/yr	1.9
n-Hexane	10.3 tons/yr	9.4 tons/yr	1.1
Naphthalene	1.3 tons/yr	0.001 tons/yr	1300
Toluene	10.3 tons/yr	7.9 tons/yr	1.3
Xylene	20.7 tons/yr	10 tons/yr	2.1

One explanation for the difference between the two models' results is that SIMS considered the waste to be oily; emissions from a floating oil layer were calculated as a function of each chemical's vapor pressure (i.e., Raoult's Law). IWAIR does not have the capability to consider waste in a surface impoundment as "oily", so its emission estimates are all based on Henry's Law (appropriate for aqueous wastes). IWAIR should either include an "oily waste" option for surface impoundments, or the documentation should explain why the aqueous waste characterization is appropriate in all cases.

I found several problems or inconsistencies with the surface impoundment module during this one test case, as follows:

- No user option to characterize waste as oily or aqueous. If there is a floating oil layer, the Raoult's Law estimation method is probably more appropriate, even if the oily layer constitutes less than 10% of the waste.
- If oily wastes are to be considered, then the solubility limit in the program (based on aqueous solubility) needs to be modified. Solubility in the oily layer may exceed the aqueous solubility.
- I noted the following problems with the printed output from the model:
    - At the input screen, Total Organics into the WMU is requested in units of mg/L. In the printed output, this parameter is incorrectly shown with units of grams/liter.
    - The output shows parameters and values pertaining to aerated impoundments, even when the aerated option is not selected. It would be better to not list this irrelevant information.

Back Calculation Option. I ran a landfill scenario in both the forward and back calculation modes. I found that when I took the predicted protective concentrations from the back calculation (based on a 1E-06 cancer risk level) and used these values as input in a forward calculation, the correct cancer risks were calculated. While not an exhaustive evaluation, this suggests that the back calculation method is reasonably accurate. However, through this exercise I noted the following problems with the model output:

- When selecting the print option, after entering the facility information, IWAIR requires the user to go back and specify a target Hazard Quotient (HQ) value, even if the compound being modeled has no RfC (which was the case for the benzene example I ran). The user should not be required to enter this irrelevant information in order to print results. After entering an arbitrary HQ value, all of the previously entered facility information is lost and the user is required to re-enter it before printing.
- The back calculation output lists emission rate values for each compound as both aqueous and oily wastes. The meaning of these numbers is unclear, but they clearly are not the emission rates associated with the predicted protective concentrations, since they are constant for each receptor distance considered. In matched forward calculation examples, the emission rate varies with the input waste concentration, as expected. The emission rate values printed on the back calculation output either should be suppressed or explained.
- I ran a relatively nonvolatile carcinogen, benzo(a)pyrene, in one back calculation. On the final calculation screen, a pop-up box gave the message that the maximum possible waste concentration yields risks below the

target level. However, the printed output does not contain this information. These type of results should be footnoted accordingly on the printed output.

ISC3ST Comparison.[6] I ran ISC3ST with a 5-year Detroit, Michigan meteorological data set to compare dispersion factors with those programmed in IWAIR. The main reason for performing this analysis was to see how representative the IWAIR regional meteorological station (Chicago, IL) would be for a Detroit, MI case. I modeled a square area source with an area of 12,546 square meters, which is the same as one of the areas shown in Table 3-4 of the Technical Background Document. I placed receptors 25 meters from the edge of the area, in 16 directions, equally spaced around the area, to match the method used to develop the IWAIR dispersion factors. The emission rate modeled was 1 $\mu g/m^2$-s, to yield Unitize Air Concentrations (UACs) directly comparable to those in Table 3-4 and the IWAIR output.

The highest 5-year average dispersion factor at any of the 16 modeled receptor locations was 2.15 $\mu g/m^3$ / $\mu g/s$-m^2. The IWAIR dispersion factor based on the Chicago station was 2.8 $\mu g/m^3$ / $\mu g/s$-m^2, which results in a 30% overestimate of risk. This degree of conservatism is reasonable for a screening model.

Table 3-4 of the Technical Background Document (page 3-11) shows the UAC for Chicago as 10.505 $\mu g/m^3$ / $\mu g/s$-m^2, which is 4 times the dispersion factor actually used by IWAIR. There appears to be a systematic error in Table 3-4.

[6] A paper copy of this model run has been submitted to EPA (se Attachment E). It is not available in electronic format.

ATTACHMENT A

Check of IWAIR Carcinogenic Risk Calculation
and Example IWAIR Model Run

Arthur Schatz: August 1999

Check of IWAIR Carcinogenic Risk Calculation
(addendum to comment on Question #19)

Page 6-1 of the IWAIR Technical Background Document describes the method used by IWAIR to calculate air concentrations and cancer risks. The following two equations are used:

Eq. 6-1 Cairj = Ej x 1,000,000 x DF

where:

Cairj = air concentration of chemical j (ug/m3)
E = volatile emission rate of chemical j (g/m2-s)
DF = dispersion factor ([ug/m3] / [ug/m2-s])

Eq. 6-2 Riskj = (Cairj x 0.001 x CSFj x EF / (AT x 365)) x sum (IRi x EDi / BWi)

where:

Riskj = individual risk for chemical j (unitless)
Cairj = air concentration for chemical j ([µg/m 3])
CSFj = cancer slope factor for chemical j (per mg/kg-d)
i = index on age group (e.g., <1 yr, 1-5 yr, 6-11 yr, 12-19 yr, adult)
IRi = inhalation rate for age group i (m 3 /d)
EDi = exposure duration for age group i (yr)
EF = exposure frequency (d/yr)
BWi = body weight for age group i (kg)
AT = averaging time (yr) = 70

For this evaluation, the emission rates (E) and dispersion factor (DF) in Equation 6-1 were either supplied by the user or calculated by IWAIR. To solve Equation 6-2 for a resident, the summation term [sum(IRi x EDi / BWi)] was first calculated based on the values for IR, ED, and BW given in Table 4-1 of the Technical Background Document. The following table summarizes this calculation:

Receptor	Exposure Duration ED (yr)	Inhalation Rate IR (m3/d)	Body Weight BW (kg)	IR x ED / BW
Child <1	1	4.5	9.1	0.49
Child 1-5	5	7.55	15.4	2.45
Child 6-11	6	11.75	30.8	2.29
Child 12-18	7	14	57.2	1.71
Adult Resident	11	13.3	69.1	2.12
SUM {IR x ED / BW} :				9.07

The remaining values needed to calculate risk according to Equation 6-2 are CSFj, EF, and AT. The values for CSFj were taken from the IWAIR database as printed on the model output report. EF and AT for the residential scenario are defined as: 350 days per year and AT is defined as 70 years.

EF: 350 days/yr
AT: 70 years

Cancer risks were calculated for two residential exposure scenarios: vinyl chloride from a landfill; and benzene from a surface impoundment (see the accompanying IWAIR reports for each scenario). The following table summarizes my independent risk calculation and the corresponding IWAIR model results.

Case	Compound	CSF (per mg/kg-d)	Ej (g/m2-sec)	DF ([ug/m3]/[ug/m2-s])	Cairj (ug/m3)	Cancer Risk		Ratio Calc'd : IWAIR
						Calculated	IWAIR	
Landfill	Vinyl Chloride	0.3	2.20E-07	4.4	9.68E-01	3.61E-05	3.90E-06	9.25
Surface Impoundment	Benzene	0.029	1.00E-06	2.15	2.15E+00	7.74E-06	8.40E-07	9.22

ATTACHMENT B

Example of Duplicate IWAIR Model Runs
Producing Inconsistent Results

[A paper copy of these model runs has been submitted to EPA. They are not available in electronic format.]

ATTACHMENT C

Example IWAIR Model Runs

Landfill Scenario (2 model runs)

- 12 Landfill Cells
- 24 Landfill Cells

[A paper copy of these model runs has been submitted to EPA. They are not available in electronic format.]

Arthur Schatz: August 1999

ATTACHMENT D

Example IWAIR Model Run

Surface Impoundment: API Separator

[A paper copy of this model run has been submitted to EPA. It is not available in electronic format.]

ATTACHMENT E

Example IWAIR Model Run

ISC3ST Comparison for Surface Impoundment:
User Input Emission Rate and Dispersion Factor

[A paper copy of this model run has been submitted to EPA. It is not available in electronic format.]

Arthur Schatz: August 1999